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ALGOL:

THE

"GHOUL" OR "DEMON" STAR.

A SUPPLEMENT TO

"THE EARTH STANDS FAST."

BY

J. WATTS DE PEYSTER

AND

FRANK ALLABEN.

NEW YORK:
CHARLES H. LUDWIG, PRINTER, 90 WALKER STREET.
1900.

JOHN WATTS DE PEYSTER,

BREV. MAJ.-GEN., M. A., LITT. D., PH. D., LL. D.

DECEMBER, 1895. (AGED 75-76.)

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> "Many learned people are not as widely read as they are supposed to be."
>
> "Most people will not receive a great new truth, not because of want of evidence, but because it requires a complete readjustment of their mental furniture; and most people's furniture is *screwed down* to the flooring of the mind in such wise that it requires a ripping up of the whole mental structure."—Quotations from Macqueery's "Evolution of Man and Christianity."
>
> "Of all the ways of Providence, nothing is so inscrutable as the littleness of the minds that control the destinies of great nations."—VOLTAIRE.

NEW YORK:
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"Be it as it may, it must be laid down that I curse the accursed lumber-room of this modern conception [popular accepted hypothesis]; and certainly some young ingenious man will rise who has the courage to oppose this universal crazy nonsense. The repeated assurance which all natural philosophers have had in this same conviction is the most outrageous thing you can hear. He, however, who knows men knows how this happens. Good, able, keen brains make up such an opinion on the basis of probability; they assembly proselytes and disciples; such a mass gains literary power; one magnifies the opinion, exaggerates it, and carries it out with a certain passionate excitement; hundreds and hundreds of well-thinking normal men, who are active in other branches and also wish to see lively working in their surroundings, honored and respected—what can they do better and wiser than to give these ample scope, and to consent to what is not their business? And this is then called general agreement of scholars!"

GOETHE.

"There is, perhaps, no phase of the human mind more curious or inexplicable than that state of servile submission to authority in matters of belief which characterizes the majority of mortals. It is, indeed, a humiliating spectacle to behold full-grown men depending implicitly for opinions on the dictates of their fellow-men; prostrating their intellect, distrusting the evidence of their senses, and absolutely turning a deaf ear to conclusions, however obvious, if not reaching them through the channel of acknowledged authority! Can they not comprehend that just conclusions are to be attained alone by a studiously-careful consideration of a subject in all its bearings, not by adopting the views—the mere *ipse dixit*—of any man? By the latter course, we not only invest ourselves in a tattered garment of prejudices which every one can see through, but we must also cede the fact, that we have purloined the disreputable clothing which we parade. Now, as there is no position so fatal to the admission of truth as the position of prejudice, so is there no prejudice so degrading as that which is purloined. We do not hesitate to say, that the progress of science in this country is arrested by the strong hand of self-elected authority, and the promulgation of scientific truth retarded by those who arrogate to themselves an exclusive monopoly of philosophic lore. This state of affairs is baneful in two ways: it not only checks the dissemination of recently-discovered truths, but it invests the select few with the power of disseminating and positively enforcing the reception of error. It moreover persecutes, with relentless severity, every individual who may have the courage to expose the blunders of any magnate whose influence upon the distribution of the scientific patronage of government, and of learned societies, might be thereby compromised."—*Westminster Review.*

"In searching after truth, pursuing my attempts after knowledge of all that takes place on the earth, I saw the works of God pass before my eyes, and I discovered that man, even if day and night he refuse sleep to his eyes, he yet cannot understand those things which happen under the sun. No, from whatever effort he makes, whatever research he undertakes, there are no results, and the so-called wise man that pretends to know something really understands nothing at all. . . . Man knows nothing. Everything he touches is Vanity."—RENAN.

ALGOL:

A SUPPLEMENT TO "THE EARTH STANDS FAST."

BY

BREV. MAJ.-GEN. J. WATTS DE PEYSTER

AND

FRANK ALLABEN.

PREFACE.

In July of this year an eighty-page pamphlet, advocating the Tychonic hypothesis of the physical universe, was issued from the press. It contained an introduction and concluding remarks by General de Peyster, an English translation of the Lecture (7th Edit.) delivered in Berlin, in 1854, by Dr. C. Schoepffer, entitled "The Earth Stands Fast: Proofs that the Earth Revolves Neither upon its own Axis, nor yet about the Sun," and a letter by Frank Allaben maintaining at some length the same views and calling attention to the fact that the Tychonic hypothesis is identical with the system assumed as true in the Bible. Gratuitously supplied to all who applied for it, the first edition of this pamphlet is already nearly exhausted, its publication having attracted attention. The present pamphlet, offering some considerations not included in the larger one, is put forth as a Supplement.

Some correspondents have inquired whether eclipses, &c., can be made on the basis of Tychonic theory. All astronomers agree, as all geometricians must who examine the subject with a little care, that all the celestial phenomena known to us are explained as rationally by this hypothesis as by that of Copernicus. The objection to the Tychonic system which has the greatest real force is the supposed improbability that the sun, with its so much greater bulk but lesser density than the earth, should revolve around the latter with the astonishing velocity necessitated by a daily revolution, provided the sun is 93,000,000 miles distant from the earth, as astronomers now believe. The remarkable phenomena presented by the stars Algol and Mizar, and the comets of 1843 and 1811, as deduced under Copernican theory, we here present as a striking check to any inclined to despise Tychonic theory on such grounds. Other considerations will be found briefly touched upon.

J. WATTS DE PEYSTER.
FRANK ALLABEN.

TIVOLI P. O., Duchess Co., N. Y.
August 3, 1900.

PART I.

ALGOL.

Algol ("the demon" or "ghoul"), or β Persei, is a remarkable variable star, ordinarily of the second magnitude, in the head of Medusa in the northern constellation of Perseus. It passes through a period of 68.8 hours, during about 58 of which it shines as a star of the second magnitude, while during the rest of the period its lustre gradually diminishes until it is but two-fifths of the normal lustre, the star then appearing like one of the fourth magnitude for about twenty minutes, after which the lustre gradually increases again to normal.

An explanation of this phenomenon at once occurred to astronomers, being first suggested by Goodricke in 1783. By supposing Algol to be describing a nearly circular orbit around some dark body every 69 hours, or vice versa, the plane of this orbit very nearly coinciding with the plane of the earth's orbit, a perfectly rational explanation is apparent. For in that case the dark companion of Algol at one point in the orbit would pass between Algol and the observer on the earth, effecting a partial eclipse of the "demon star," and thus causing its periodical decrease in brilliancy. This explanation seems so rational that few questioned it, even at a time when it could not be corroborated by means of observation. Thus Prof. R. A. Proctor wrote:

"Two or three hundred stars are now recognized as variable. The most probable explanation of the variation in long periods is that stars so affected have periodical maxima and minima of disturbances, resembling that which causes the sun spots, only more marked. Some of the variables of short period are probably covered unequally in different parts of their surface by spots. But the variation of such stars as Algol, which shine with a constant lustre for the greater part of each period, and are reduced in lustre for a short interval, cannot be thus explained, and we must suppose that a large opaque orb circling around them transits [partially eclipsing] the central luminary at regular intervals." *

The only correction of this explanation required, as the fruit of the delicate spectroscopic observations of Professor H. C. Vogel, Director of the Astro-Physical Observatory at Potsdam, Prussia, is the conception of a central dark orb instead of a "central luminary:" the sun in this case, if such Algol is, revolving around the smaller opaque body. If gravitation is the controlling energy of this system, we should also expect the dark companion at the same time to revolve about Algol.

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* Article "Astronomy." Encyclopædia Britannica, 9th ed., vol. ii., p. 819.

Most readers are probably familiar with the theory that light is propagated through space as waves in the ether. Sunlight is a composite of a practically infinite series of waves, no two of which are of exactly the same length. Waves of different lengths impart different sensations to the nerves of the eye, producing the different colors which we distinguish. When all the different waves in the sunbeam blend together, each contributing its part toward the sensation imparted to the visual nerves, ordinary sunlight is perceived by us. If only the longest waves which affect the visual nerves reach us, a red color sensation is the result; if only the shortest reach us, violet light is perceived. Between these are all the gradations seen in the rainbow. Waves still longer than those which impart the sensation of redness do not affect the visual nerves, but impart the sensation of heat; while waves still shorter than those which produce the sensation of violet color do not affect the sight, but produce chemical effects such as tanning the face or decomposing the solution on a photographic plate.

A prism, when it receives a beam of light, refracts the light and also separates the waves of different wave-lengths, arranging them so that they are displayed in order, in a regular gradation from the longest to the shortest. This arrangement is called the spectrum, and in the visible part of the spectrum we see a continuous band of manifold colored light, shading off gradually from red to orange, yellow, green, blue, indigo, violet. When the light from a distant star is passed through a prism, and thus arranged in a color band, motions of the star, approaching or receding in the line of sight, are revealed by fluctuations in the spectrum. When a star is approaching us, the whole system of lines in the color band shifts toward the violet; if it is receding, the shift is toward the red. The velocity of the star, in either direction, is estimated from the amount of the shift. This is the principle upon which the delicate observations of Algol by Prof. Vogel in 1889-91 are based. Some time ago Sir Robert S. Ball, the well-known mathematical astronomer, published a popular account of the conclusions of Prof. Vogel in the case of Algol, and from Prof. Ball's article we extract the following statements:

"The case of a star which dispenses light of perfect simplicity of composition is one that can hardly exist among the heavenly bodies, though it may be admitted that there is a certain approach to it in one or two remarkable cases. It is, however, much more usual for the light from a star to be of a highly composite type, including rays not only from all parts of the visual spectrum, but also of rays belonging to the ultra-violet region, as well as others beyond the extreme red end. . . .

"It seems that in the skilful hands of Vogel and Keeler it is possible in favorable cases to obtain determinations of the velocities of objects in the line of sight with a degree of precision which leaves no greater margin for doubt than about five per cent. of the total amount. . . .

"For two days and ten hours the star [Algol] remains of uniform lustre, being ranked about the second magnitude; then a decline of brightness sets in, and the star in a few hours parts with three-fifths of its brightness. At the lowest point it remains for about twenty minutes, and then the brilliancy commences to increase, so that in a few hours more Algol has resumed its original character. The entire period required for the decline and the rise is about ten hours, and the whole cycle of the changes has been determined with much accuracy, and is at present two days, twenty hours, forty-eight minutes, fifty-two seconds. The length of the period seems to undergo some trifling fluctuations of a few seconds, but on the whole the permanence of the system is a striking part of the phenomenon. . . .

"The existence of the dark companion was . . . almost destitute of support from observations until Vogel made his wonderful discovery. Applying the improved spectrographic process to Algol, he determined on one night that Algol was retreating at a speed of twenty-six miles a second. . . . . When, however, Vogel came to repeat his observations, he found that Algol was again moving with the same velocity, but this time the movement was towards the earth, instead of from it. . . . It appeared that the movements of Algol to and fro were strictly periodic; that is to say, for one day and ten hours the star is moving towards us, and then for a like time it moves from us, the maximum speed in each advance or retreat being that we have mentioned, namely, twenty-six miles a second. The interest awakened by this discovery culminates when it appears that this movement to and fro is directly associated in a remarkable manner with the variation of Algol's lustre. It is invariably found that every time the movement of retreat is completed, the star loses its brilliance, and regains it again at the commencement of the return movement. . . . It is impossible for a star to run along a straight line for a certain distance, stop, turn back, again retrace its movements, stop, and again return. Such movement is simply forbidden by the laws of motion. . . . There is no objection to the supposition that Algol is moving in a path which is nearly, if not exactly, a circle. In this it would only be moving as does the moon, or the earth, or any of the other planets. It will be only necessary to suppose that the plane of the orbit of Algol is directed so that it passes near the earth. During the description of one semicircle Algol will be coming towards us, while during the other semicircle it will be going from us, and thus the observed facts of the movement are conciliated with the laws of motion. Of course this involves a certain periodic shift in the position of Algol in the heavens. It must, for instance, when moving most rapidly from us be at a distance equal to the diameter of the circle from the position which it has when moving most rapidly towards us. This is true; but the extent of the shift of place is far too small to be visible to our instruments. . . . It is one of the extraordinary characteristics of the spectroscopic method that it renders such an orbital movement perceptible. . . . Such a movement is possible on one condition and only one, and that is that there is an attracting body in the neighborhood around which Algol revolves. . . . The essential point to be noticed is that the spectroscopic evidence admits of no other interpretation save that there must be another mighty body in the immediate vicinity of Algol. . . . Algol must be attended by a companion star, which, if not absolutely as devoid of intrinsic light as the earth or the moon, is nevertheless dark relatively to Algol. Once in each period of revolution this obscure body intrudes between the earth and Algol, cutting off a portion of the direct light from the star and thus producing the well-known effect.

"There are several cases in which, though we are not able to measure the dimensions of stars, yet we are able to weigh them. If the period of revolution of a binary star has been determined, and if the distance of the pair from the sun is also known, we then have sufficient data to enable us to compare the mass of the binary system with that of the sun. . . .

"It is surely a noteworthy epoch in the history of astronomy when, for the first time, we are able to apply the celestial calipers to gauge the diameter of a star. So far as surveying and measuring goes, this is the most significant piece of work in sidereal astronomy since the epoch, half a century ago, when the determination of a stellar distance first emerged from the mistiness of mere guess-work and took a respectable position among the solved [?] problems of astronomy. . . .

"Algol, at the moment of its greatest eclipse, has lost about three-fifths of its light; it therefore follows that the dark satellite must have covered three-fifths of the bright surface. It is also to be noticed that the period of maximum obscuration is about twenty minutes, and that we know the velocity of the bright star. These facts, added to our knowledge that ten hours is required for the brilliancy to sink from and regain its original lustre, enable the sizes of the two globes to be found. There is only one element of uncertainty in the matter. We have assumed that the densities of the two bodies are the same. Of course this may not be the case, and if it should prove to be unfounded then some modification will have to be made in the numerical elements now provisionally assigned. . . .

"[Algol] is indeed a vast object, a glowing globe, a veritable sun, much larger than our own. The diameter of the sun would have to be increased by almost two hundred thousand miles to make it as great as that of Algol.

"Imagine two globes, each as large as our sun, let these two be rolled into one, and we have a globe of the splendid proportions of Algol. . . .

"Though Algol is twice as big as the sun it is not twice as heavy. It is indeed an extraordinary circumstance that, notwithstanding the vast bulk of Algol, its weight is only about half that of the sun. The sun itself has a density about a fourth that of the earth, or but little more than the density of water, yet Algol has a density which is much less than that of water; in fact, this globe is apparently not much heavier than if it were made of cork. We are, of course, speaking of the average density of the star. No doubt its central portions must be dense enough, but it is impossible to resist the conclusions that the greater part of Algol must be composed of matter in a gaseous state. Of course such a state of things is already known to exist in many celestial bodies. . . .

"It appears that the companion of Algol is about the same size as our sun, but has a mass only one-fourth as great. This indicates the existence of a globe of matter which must be largely in the gaseous state, but which, nevertheless, seems to be devoid of intrinsic luminosity. We may compare this body with the planet Saturn—of course the latter is not nearly so large as the companion of Algol, but the two globes seem to agree fairly well as to density. . . .

"The movements of binary stars have been studied, and it has been invariably found that the phenomena observed are compatible with the supposition that the law of gravitation prevails throughout the universe. It would not, however, be correct to assert, as has been sometimes done, that the facts of the binary systems actually prove that gravitation is the all-compelling force there as here. The circumstances do not warrant us in expressing the matter quite so forcibly. The binary stars are so remote that the observations which we are enabled to make are wanting in the almost mathematical precision which we can give to such work when applied to the bodies of our own system. It is quite possible for mathematical ingenuity to devise a wholly abitrary and imaginary system of force, which might explain the facts of binary stars, as far as we are able to observe them, on quite another hypothesis than the simple law that the attraction between two particles varies with the inverse square of the distance. . . .

"There is one point in which the Algol system presents features wholly without parallel in the planetary movements. It is that the two bodies are so very close together. I do not, of course, mean that they seem close by ordinary standards—for is not their distance always some three million miles? This is, however, an unusually short distance when compared with the dimensions of the two globes themselves. The dimensions of the system may be appreciated by the simple illustration of taking a shilling and a sixpence and placing them so that the distance from rim to rim is two inches. The smaller coin will represent the dark satellite and the larger one Algol, fairly correct as to position and dimensions. Viewed in this way, it is evident that the dimensions of the globes bear a monstrous proportion to their distance apart when compared with the more familiar planets and satellites of our system. The tides in such a case must be of a magnitude and importance of which we have no conception from our experiences of such agencies here." *

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* Article, "The New Astronomy: Its Methods and Results," by Robert S. Ball. Published in the *Fortnightly Review* and reprinted in *Littell's Living Age*, No. 2487, February 27, 1892.

Were we interpreting the observed phenomena in the case of Algol on the basis of Tychonic theory, we would not, of course, be compelled to postulate such a scale of dimensions and distances for the system; but on the basis of Newtonian-Copernican theory it is logically deduced. Thus Copernican hypothesis itself affords us a remarkable analogy, in many respects, to what most persons will consider the most improbable feature of the Tychonic system—the postulate of a daily revolution of the sun around the earth. True, the orbit of Algol about its dark companion is much less than that of the sun around the earth (if we concede the current estimate of the distance of the sun from the earth), while the daily revolution requires sixty-nine instead of twenty-four hours, so that the velocity of Algol is very much less than that required for the sun, 93,000,000 miles distant from the earth, to encircle the latter in twenty-four hours. But, on the other hand, Algol presents features which are apparently much more incredible than any involved in the Tychonic hypothesis respecting the sun.

According to Prof. Vogel, Algol is twice the size of the sun, but with only one-half its mass, or weight, so that its density is but one-fourth that of the sun. According to him Algol has a diameter of more than a million miles; its dark companion has a diameter which is very nearly that of our sun, or about 830,000 miles, while these two immense bodies approach within nearly three million miles of one another, without coalescing. May we not justly view with suspicion the dynamical reasoning which sees nothing extraordinary in such propinquity of bodies so enormous, induced by uniformly-acting attraction which is proportional to the great masses involved, and as they approach one another increases inversely as the square of the distance between them diminishes?

If all the planets and moons of our entire solar system were combined in one globe, it would require one hundred and sixty such globes merged into one to form an orb with the mass attributed to Algol's dark companion. Imagine this enormous mass, one hundred and sixty times that of all the planets and satellites of our system, as the centre about which revolves another mass, twice as great, in an orbit only one-one-hundred-and-seventy-fifth as large as that of Mercury around the sun, at a velocity less than that of Mercury! In fact, the diameter of the orbit assigned to Algol by Dr. Vogel is but 2,000,000 miles, which is but a very little more than the sum of the diameters of the two orbs!

The imagination is greatly needed in propounding the mechanics of such a system, or that of comets which almost touch the sun and yet speed off into space, upon the hypothesis of constantly-acting gravitation. The postulate of electrical attraction and repulsion, however, would account for such phenomena without requiring us to imagine mechanical conditions unknown at the earth's surface. From a familiar experiment we know that pith-balls or bits of paper suspended not far apart are drawn toward one another when any two of them are in opposite electrical states, whereas in virtue of their close approach an equalization of electrical states takes place in some way not yet perfectly clear to us, the result being that they fly apart again. This is a phenomenon strikingly similar to that observed in the case of celestial bodies which move in elliptical or parabolic orbits. Electromagnetic attraction varies inversely as the square of the distance, as hypothetical gravitation is said to do, but is evidently directly proportional rather to the electrical states of the bodies in the system than to their masses merely. Substituting a theory of electrical states for the theory of gravitation, we would still recognize Newton's law as a mathematical formula which is approximately correct.

PART II.

MIZAR.

MIZAR (ζ Ursæ Majoris) is a double star of the second magnitude, in the handle of the Great Dipper, or tail of the Great Bear, situated near Alcor, a star of the fifth magnitude, both of which are thought by some to form one system. Be this as it may, Mizar itself has been shown to be a double star, through the researches of Professor Pickering of Harvard University. The following references to Mizar are taken from the same article by Prof. Ball from which we have previously quoted. He says:

"The association of Alcor and Mizar is rendered highly probable from the fact that they move together in parallel directions and with the same velocity. But this is the least of the circumstances that give Mizar its interest. The star itself is a double of the easiest type. . . . This is the second noteworthy point about Mizar; but now for the third and last, which is by far the most interesting of all, and has only lately been ascertained by a discovery which will take its place in the history of astronomy as the inauguration of a new process in the study of things sidereal. Professor Pickering has, as is well known, been extremely successful in obtaining protographs of the spectra of the stars. . . . Among the stars subjected to his camera was Mizar, and the photographs of the spectrum of its principal component exhibited, as other stellar spectra did, a profusion of dark lines. These photographs being repeated at different dates, it was natural to compare them together, and it was noticed that the lines sometimes appeared double and sometimes single. . . . . Presently it appeared that this opening and closing of the lines was a periodical phenomenon. The interval between one maximum opening of the lines and the next was fifty-two days. . . . . It was plain that the object could not be a single star; it must consist of a pair extremely close together and in rapid revolution. The doubling of the lines will then be readily intelligible. When one of the components is moving towards us, while the other is moving from us, all the lines belonging to one system are shifted one way, and all those belonging to the other system are shifted the other way—the effect on the spectrum being that the lines appear doubled. When the stars are moving perpendicularly to the line of sight, then their relative velocities towards the earth are equal, and the lines close up again. We thus at once learn the period of the revolution of the two components. The lines must open out twice in each circuit, and consequently we have as the first installment of the numerical facts of the system that the period of its revolution is one hundred and four days. . . , The amount by which the lines open when they separate admits of accurate measurement, and as this depends on the velocities, it follows that we now obtain a determination of these velocities. It thus appears that the speed with which each of the component stars moves is about fifty miles a second. As, therefore, we know the pace at which the stars are moving, and the time they need for the journey, we know how large their path is, and thus we infer that the distance of the components is, speaking roundly, about one hundred and fifty millions of miles. But now we are enabled to draw a remarkable inference. We know the size of the orbits, and we know the time in which the revolutions are accomplished. It is the mathematician who enables the mass of the bodies to be determined, and the result is not a little astonishing. It tells us that the mass of the two component stars which form Mizar is not less than forty times as great as the mass of the sun." *

If the Copernican conception of the physical universe is the correct one, and gravitation is the force which controls all celestial movements, then these astonishing computations are undoubtedly correct; and whatever be the truth of the matter, if the "new astronomy" keeps on at this rate, characterized as it is by the substitution of experimental research for mathematical theorizing on a hypothetical basis, it bids fair to bring truth into her rights. But it is plain that the Tychonic system cannot be condemned because it requires a grand sweep of the imagination to conceive of the velocities of sun, planets and star-sphere without reflecting upon the credibility of Copernican theory, on account of the enormous dimensions which it assigns to many celestial spheres.

Many years ago a writer in the "Penny Cyclopædia for the Diffusion of Useful Knowledge" remarked: "One of the strong arguments against Ptolemy (and the one which has generally found its way into modern works) was the enormous motion which he supposed the stars to have. The Copernican of that day might have been compelled to choose between an incomprehensively great magnitude and a similar motion." It begins to appear that the Copernican of the present day is to be shut up to the same alternatives!

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* *Ibid.*

PART III.

THE VELOCITIES REQUIRED BY THE TYCHONIC SYSTEM CONTRASTED WITH THOSE DEDUCED FOR THE GREAT COMETS OF 1843 AND 1811 UNDER NEWTONIAN-COPERNICAN THEORY.

The "strong argument" against Ptolemy referred to just above, namely, "the enormous motion which he supposed the stars to have," also operates against Tycho Brahe's system, and, to one taking a superficial view of the subject, might seem fatal to it. But let us state this argument against the Tychonic theory in the strongest terms, and see what it amounts to.

In Tycho's day it was thought that the sun was distant from the earth several million miles, and even at such a distance it seemed almost incredible that the great solar luminary should be capable of a velocity sufficient to enable him, in twenty-four hours, to circumscribe the earth. But if this was a difficulty in those days, how much more so now, when we estimate that the sun is distant from us 93,000,000 miles. The positions and movements assigned to the earth and sun in the Copernican system are exactly reversed in the Tychonic system, the annual orbit now assigned to the earth becoming the *daily* orbit of the sun. But is it rational to conceive of the sun as encompassing in twenty-four hours the immense orbit which, under current theory, we think of the earth—travelling more than nineteen miles a second —as requiring a year to circumscribe? This is the strongest indictment of the Tychonic system which has ever been advanced.

But let whoever stands aghast at this conception reflect that Newtonian-Copernican theory already staggers under the postulate of velocities beside which those required by Tychonic theory are mere child's play! Let such an one consider the speed with which, provided the Copernican scale of distances is correct, some comets sweep through the luminiferous ether, the subtile, resisting fluid which probably pervades all space. The reader may refer to any good astronomical work which treats of comets. A single example will suffice, that of the great comet of 1843, the tail of which was visible for sixty-five degrees against the heavens, representing an actual length (if we can credit Newtonian-Copernican measurements) of one hundred and fifty million miles, or nearly the length of the diameter of the earth's alleged orbit about the sun. The following account of the performances of this comet is taken from an elementary but careful work, which many readers may have at hand:

"This comet is especially remarkable on account of its near approach to the sun. At the time of its perihelion passage the distance of the comet from the photosphere of the sun was less than one-fourteenth of the diameter of the sun. . . . When at perihelion, this planet was plunging through the sun's outer atmosphere at the rate of one million, two hundred and eighty thousand miles an hour. It passed half way round the sun in the space of *two hours*, and its tail was whirled round through a hundred and eighty degrees in that brief time. As the tail extended almost double the earth's distance from the sun, the end of the tail must have traversed in two hours a space nearly equal to the circumference of the earth's orbit—a distance which the earth, moving at the rate of about twenty miles a second, is *a whole year* in passing." *

If we accept the Newtonian-Copernican hypothesis, and concede that the mean distance from earth to sun is 92,700,000 miles, we must then believe that the extremely tenuous matter at the extremity of this comet's tail moved with ten times the velocity required for the sun to revolve about the earth in twenty-four hours. If the distance to the sun be indeed approximately as now computed, then his daily orbit around the earth, according to the Tychonic theory, is about 582,700,000 miles in length. To travel this distance in twenty-four hours he must move with a velocity of about 6744 miles a second. But for the extremity of the tail of the comet of 1843 to cover the like distance in two hours required a velocity of over 65,400 miles a second, or more than one-third the estimated velocity of light!

Hence this velocity which Copernican philosophers are compelled by the exigencies of their theory to postulate for the tail of the comet of 1843 would be ten times as incredible as the velocity of the sun assumed by Tychonic theory, even if the comet's tail had been of a density equal to that of the sun. But, on the contrary, the tails of comets undoubtedly consist of gaseous matter, of a tenuity beyond anything we know on the earth, and by as many hundreds or thousands of times as the matter in this comet's tail was less dense than in the sun's bulk, by that many hundreds or thousands of times is the velocity postulated by Copernican theory in this case less credible than that required by Tychonic theory.

If we concede Newton's hypothesis of universal gravitation, then this extreme tenuity of comets is demonstrated by the fact that such bodies have enveloped planets without possessing sufficient mass and consequent energy of attraction to cause the least perturbations of the planets which astronomical instruments could detect; while, on the other hand, the influence of planets easily diverts comets from their orbits. The tenuity is also shown by the fact that very faint stars are discernible through comet's tails, consisting of matter certainly a million miles thick, if our current scale of magnificent distances be allowed. Again, twice during this century, according to astronomers, the earth passed through the tail of a comet, while not even an effect upon our atmosphere was discernible. Through a resisting medium—so subtile, indeed, that it exercises no appreciable retarding effect on denser bodies, but which was supposed to exercise such an effect on the exceedingly light vapors of which comets are composed, as in the case of Encke's comet—Newtonian-Copernican theory compels us to credit the tail of the comet of 1843 with having swept at a velocity of over 65,000 miles a second! If bodies with scarcely any density can *flash* through space with almost the velocity of light, or as lightning flashes in the denser medium enveloping the earth, what limit shall we set to the velocity which may be possible for an orb so dense as the sun, propelled by the operation of the enormous energy which drives the whole planetary system, and the whole stellar system, through the realms of space?

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* "The Heavens Above: A Popular Handbook of Astronomy." By Prof. J. A. Gillet and W. J. Rolfe. New York: 1882. p. 296.

But will the reader who refuses to credit the velocity required by the Tychonic hypothesis of the sun's daily revolution around the earth, seek to avoid the far greater Copernican difficulty by refusing to credit the velocity attributed to the comet of 1843? This way of escape is not open to him. Rejection of the computed velocity of the tail of this comet is logically permissible only for one who positively rejects the current theory and scale of distances! Admit these premises, and this magnificent velocity of a mammoth cloud of attenuated gaseous substances simply becomes a matter of mathematical calculation!

But great as is the velocity computed for the extremity of the tail of the comet of 1843, it is not one-half that computed by Olbers for the particles of matter which flashed from the head to the tail of the notable comet of 1811. Measured by the accepted standards, the tail of the latter was 120,000,000 miles in length, and yet we are required to believe that material particles expelled from the comet's nucleus swept to the extremity of the tail in eleven minutes, or at a velocity of more than 181,000 miles a second! This is more than twenty-five times the velocity which Tychonic theory requires of the sun, 92,700,000 miles distant from the earth, in order to circumscribe the latter in twenty-four hours! The velocity assigned to the particles of this comet is, in fact, almost that of light, which is 186,328 miles a second, according to the experimental determination of Prof. Newcomb. Nor should it be forgotten that the velocity assigned to these particles was in a direction away from the sun, so that the force of repulsion which achieved such a result had to overcome the attractive pull of the sun for the particles—provided there is any truth in the accepted hypothesis of gravitation! After this instance of the tax upon credulity which Copernican hypothesis is capable of levying, let no one mention the modest velocities required, as an objection to Tychonic theory!

The authors of this pamphlet are logically entitled to question the orthodox conclusions in the case of this and other comets, because they call in question the premises upon which their elements have been computed. But this rational skepticism is allowable only for such of our readers as are, with us, satisfied with the sufficiently astonishing marvels involved in Tychonic theory. We leave it to Copernican mathematicians, driven by the exigencies of their astronomical creed, to postulate of some comets, spite of their tenuity, velocities beside which those predicated, by Tychonian hypothesis, of sun, moon, planets and stars, in view of the vastly greater densities of these bodies, are positively insignificant !

PART IV.

CHEMISTRY vs. NEWTONIAN PHYSICS.

[*Extract from a Letter.*]

ROSE HILL, Tivoli P. O., Duchess Co., N. Y.
August 2, 1900.

Mr. ——— ———

DEAR SIR :—I am here, visiting my friend, Gen. J. Watts de Peyster, who has just shown me your courteous acknowledgment of the receipt of his pamphlet, "The Earth Stands Fast," to which I am a contributor. . . .

General de Peyster and myself have entertained our rather surprising view, as skeptics respecting Newtonian-Copernican theory, for a number of years. During the last ten years I have sought to equip myself to approach the question rationally by a study of astronomy, physics and chemistry in the best authorities accessible to a student in New York City. I find that the astronomer and physicist who work downward on the basis of Newtonian hypothesis, and the chemist who works upward by deductions based upon experimental facts, do not arrive at a common conception of the properties of matter, and in making choice between the two conceptions I unhesitatingly take my stand upon the experimental science of the chemist. I have just prepared a summary of what I consider very grave scientific reasons for questioning Newtonian theory, and I will mention some of them here. . .

Astronomy has been a fertile field for "paradoxists," who have advanced the most chimerical fancies in the name of science. But Gen. de Peyster's pamphlet attempts nothing of the sort. It maintains no new theory, but revives that of a famous astronomer, Tycho de Brahe, which astronomers have ever conceded to be the equal of the Copernican hypothesis in respect to its absolute competency to explain, on mechanical principles known to us, all the astronomical facts ascertained by observation to the present time. Any one may satisfy himself that this is fact by consulting almost any reliable astronomical work which discusses the respective merits of the two systems.

The excellent "Penny Cyclopædia of the Society for the Diffusion of Useful Knowledge" (vol. v., p. 326) says: "The real state of the case is this: that the latter [Tycho Brahe] did compound, out of the systems of Ptolemy and Copernicus, a system of his own which, while it seized by far the greater portion of the advantages of the latter, was not open to the most material objection. . . . And we assert, moreover, that of all the inconclusive arguments of that day which concern the subject in question, the reply of the Copernicans to Tycho Brahe is the most inconclusive. The system of Tycho Brahe consists in supposing: 1. That the stars all move around the earth as in the Ptolemaic system; 2. That all the planets, except the earth, move around the sun as in the Copernican system; 3. That the sun, and the imaginary orbits in which the planets are moving, are carried around the earth. Imagine a planetarium on the system of Copernicus placed over a table above which is a light. As the earth moves, let the whole machine be always so moved that the shadow of the earth shall fall upon one and the same part of the table. Then the motions of the shadows of the other planets and of the sun will be according to the system of Tycho Brahe. *Mathematically speaking, it does not differ from that of Copernicus.*" (Italics mine.)

The author of the article on "Astronomy" in the same work says (vol. ii., p. 534): "Tycho Brahe did not admit the Copernican theory; but substituted for it one of his own, usually known by the name of the Tychonic system. This consisted in supposing the sun to move around the earth, but all the other planets to move around the sun, being also carried with it around the earth. This system *explains all the appearances as well as that of Copernicus.*"

I cite another authority to the same effect, the late Prof. R. A. Proctor, in his treatise on "Astronomy" in the Encyclopædia Britannica, 9th edition (vol. ii., pp. 777-8). He declares: "It is not too much to say that Tycho's system is not only *fully equal to the Copernican in its fitness to explain the observed relations*, but that . . . the arguments for the Tychonian system, modified so as to correspond to Kepler's discovery of the shapes of the different orbits, were almost equal in weight to those used by the disciples of Copernicus." (Italics mine.) He adds that "the geometrical relations are precisely the same" for the two systems.

True or false, Tycho's hypothesis has the same inherent dignity as that of Copernicus, even as the latter was remodeled by Newton — it rationally accounts for all the astronomical phenomena known to us without involving a single scientific absurdity. In these days of "higher criticism," when the Bible has been subjected to flings on every hand, on the alleged ground that its astronomical ideas are primitive, childish and impossible, it is rather startling to recognize in this "primitive" system of the Bible none other than the perfectly competent system advocated by Tycho Brahe! Had we positive proof (as we have not) of the truth of the Copernican hypothesis, the fact would remain that the Bible is the only authority which has handed down from antiquity an astronomical system which is as competent as the system of Copernicus to explain all the celestial movements on rational mechanical and mathematical principles. But the believer in the inspiration of the Bible can go further, and ask: What if the Biblical system is after all the true one, since modern science cannot impeach its competency, although a rival hypothesis has the place of honor in all text-books? One so bold might be considered singular, in venturing to hold a view contrary to a universal concensus of opinion; but all the scientists in the world, with our present knowledge, could not demonstrate any absurdity in his view, nor prove it to be less plausible than the received opinion.

The most powerful objection to Tychonian theory is the apparent improbability that sun, moon, planets and the sphere of fixed stars, so-called, should move with the astonishing velocities required for a daily revolution about the earth on the basis of the current computations of their distances from us. In the case of the fixed stars, the present computations fall to the ground with the postulate of Tychonian theory. But accepting the present estimate of the distance of the sun as approximately correct, its daily revolution around the earth would involve a velocity of something like 6744 miles per second. If the extreme tenuity of some comets (gaseous bodies with a density probably much less than that of hydrogen gas under terrestrial conditions) does not prohibit us from crediting their substance with velocities through the ether of space of more than 180,000 miles per second, it does not appear that the Creator need violate any of the laws of nature, as known to us, in order to impart a velocity of less than seven thousand miles per second to a body like the sun, with one-fourth the density of the earth.

Our astronomers believe that the star, Groombridge 1830, is speeding through space at the rate of over two hundred and twenty-five miles per second. In the phenomenon of double stars, where a supposed sun revolves about another orb, astronomers credit a condition in principle not unlike that postulated of our sun in Tycho's hypothesis. If the sun's mass be considered an objection, we may consider the double star Mizar (ζ Ursæ Majoris), in which case astronomers accept Professor Pickering's conclusion that we have double stars with a mass forty times that of our sun which revolve with velocities of about fifty miles per second in an orbit one hundred and fifty million miles in length, so that they are comparatively close together.

The case of Algol should quite silence objections of this nature. This star (β Persei) has long been known to execute a cycle of changes in two days and twenty-one hours, while the fact that at one point in each revolution it loses three-fifths of its brightness long ago led to the rational deduction that it revolves around a dark body, three-fifths its size, by which it is eclipsed. Professor Vogel's spectroscopic investigation confirms this conjecture, with the conclusions that Algol is mainly if not entirely a gaseous body, with twice the bulk but only one-fourth the density of our sun, revolving about a smaller dark body every sixty-nine hours in a comparatively small orbit, in the course of which revolution Algol and its dark companion approach one another until the distance between them is but three times the diameter of Algol! An hypothesis which already conducts us to such results should not look askance upon the consequences of Tychonian theory.

The phenomena of parallax and aberration I have studied with some care, and while I am not yet ready to submit a detailed solution of the problems, I have become convinced that they can be demonstrated as readily in accordance with rational mechanical principles under Tychonian as under Copernican theory, the phenomena being assigned to movements of sun, moon, planets and star-sphere instead of to a movement of the earth.

Why should scientists seriously reconsider the Tychonic hypothesis? Because the Newtonian-Copernican system presents difficulties, so far insoluble, which have accumulated since the days of La Place, Newton's great successor, and because knowledge of the properties of matter gained by experimenters during this century does not agree with the theory of matter required by the Newtonian-Copernican scheme.

I. Prof. H. Seeliger, of Munich, Germany, and Dr. Carl Neumann, have independently arrived at mathematical demonstrations that Newton's law of universal gravitation cannot be an exact law of nature in case (1) the sum total of the masses of the universe is infinitely great, or (2) the ether of space consists of an homogenous distribution of matter. (See articles by G. W. Myers in *Popular Astronomy*, for January, 1898, and by Kurt Laves in the same for February, 1898.) These conclusions have greatly added to the uneasiness felt in connection with Newton's law.

II. Discrepancies between observed phenomena and Newtonian theory in the case of earth, moon, Mercury, Venus and Mars, with the phenomenon of repulsion in place of attraction in the case of the tails of comets when those bodies approach and recede from the sun, present problems which now at length have produced an undercurrent of skepticism among astronomers themselves. (See articles by two well-known American astronomers, Prof. Asaph Hall, in *Popular Astronomy*, May, 1897, and Prof. Simon Newcomb, in *McClure's Magazine*, July, 1899.)

III. The bearing of our present knowledge of the properties of the atoms and molecules of matter upon Newton's hypothesis that every particle of matter in the universe attracts and is attracted by every other particle, has not been boldly faced as yet by any scientist, so far as I know. But already a vague unrest is apparent, and is beginning to produce an attitude of agnosticism toward all scientific theories on the part of scientists. Such an attitude has recently been defended as the only proper one by Prof. Henry A. Rowland, of Johns Hopkins University, in his address as President of the Physical Society of America, delivered October 28, 1899, and printed in the *American Journal of Science*, for December, 1899. He takes Newton's law of gravitation, popularly supposed to be the one theory of the scientist which has been infallibly demonstrated if no other has, and shows that, on the contrary, it remains mere hypothesis, unsusceptible of demonstration. He remarks that the so-called "proofs" of Newton's law are all erected from premises in which the law *is assumed without proof*, and therefore do not demonstrate it. "Thus a proof of the law," he says, "from planetary down to terrestrial distances is physically impossible."

IV. Newton conceived of an attractive energy, proportional to the weights of the particles involved, which operates constantly and uniformly between the atoms of matter. But the chemist knows nothing of this, the chemical affinities of atoms and molecules, investigated by him, exhibiting phenomena of an entirely different order. He finds that each kind of atom and each kind of molecule reveal attractive affinities peculiar to that kind, attracting certain other kinds of atoms or molecules, but not all particles of matter, irrespective of their chemical character, nor yet any in a simple proportion to their weight.

It is true that the so-called periodic law of inorganic chemistry, now quite universally recognized by chemists as a fundamental law of nature, indicates that the properties of the atoms bear a periodic relation to their atomic weights. Mendeléeff, the famous Russian chemist and master-student of the periodic law, thought this fact might afford a connecting link with Newton's law. But this appears impossible, so long as we conceive of Newton's law as an approximately accurate expression of the operation of a force which is uniformly proportional to the weight of the particles of matter. For the periodic law does not state that the properties of atoms are functions of their atomic weights, but that they are *periodic* functions of the weights. Omitting hydrogen, and taking the next eight elements in the order of increasing atomic weights, we have, helium, lithium, beryllium, boron, carbon, nitrogen, oxygen and fluorin. Now, have we here a closely-related group of elements whose properties are proportional to the weights of their respective atoms, so that they gradually shade off from helium to fluorin, as eight adjacent lines in the spectrum of light would shade off in almost imperceptible gradations? Not at all. These eight elements, so close together in atomic weights, are the most diverse in their characters, presenting in fact the entire gamut of dissimilarity in chemical character. Helium is most inert, apparently exhibiting no affinity whatever for any other element; lithium is a metal, strongly basic, strongly electro-positive, with characteristic valence of one; beryllium is a metal, less basic, less positive, with characteristic valence of two; boron is a non-metal, more acidic than basic, more negative than positive, with valence of three; carbon is a non-metal, neutral in character but leaning toward the acidic and negative side, with characteristic valence of four; nitrogen is a non-metal, very inert, acidic and negative in character, with characteristic valence of five; oxygen is a non-metal, extremely acidic, extremely negative, very active, with valence of two and six; fluorin is a non-metal, extremely active, extremely acidic, extremely negative, with characteristic valence of one and seven. Lithium, beryllium, boron and carbon are solids at ordinary temperatures, while helium, nitrogen, oxygen and fluorin are gases.

If we take the next eight elements, in the order of gradually increasing weights of their atoms, we meet the same phenomenon: not a likeness in chemical characters proportional to their near approach in atomic weights, but a repetition of the eight distinct types of diverse chemical characters in the same order as before, neon being akin to helium, sodium akin to lithium, magnesium to beryllium, aluminum to boron, silicon to carbon, phosphorus to nitrogen, sulphur to oxygen and chlorin to fluorin. The next eight elements repeat this order of chemical types. The evidence of law and order here is most unequivocal, but the law is not that of Newton. If one of the properties of these atoms is a constant and uniformly-acting energy of attraction for all other particles of matter, the energy being proportional to the atomic weight in every case, then nothing would seem to be more certain than that this property bears no relation to those other properties which are peculiar to each atom. For the periodic law is the distinct recognition that the properties of the atoms are *not* proportional to their weights, but rather that, when the elements are arranged in the order of gradually increasing atomic weights, there is seen to be a regular recurrence of a limited number of types of chemical character.

It is as if the Creator intended by means of eight notes, eight symbolical characters, to express the meaning of all things; and having impressed these eight characters upon the first eight elements, in the order of increasing atomic weights, the next eight elements received the like stamp, the next eight were similarly characterized, and so on to the end of the list. The arbitrary nature of this arrangement cannot be disguised. Were it demonstrable that all the properties exhibited by each particle of matter are proportional to its weight, and thus simple functions of the weight, materialists might speak glibly of some blind inherent law of matter; but the evidence of a designing Intellect, in the arbitrary order recognized by the periodic law, cannot be thus expunged from nature.

On the other hand, though we cannot yet state the law of that relation, it seems perfectly plain that there is a close relation between the electrical properties of the atoms and their other properties, for the degrees of basicity or acidity, upon which the chemical affinities appear to depend, closely follow the lines of electro-positive or electro-negative character. Hence, if we dismiss the conception of universal gravitation, regarding Newton's law rather as an approximately accurate expression of the operation of electro-magnetic attraction throughout the universe, the force of which is inversely as the square of the distance and proportional to the electrical tension, then we can conceive of the possibility of arriving at a theory which will rationally explain all the celestial phenomena of the physical universe as extensions of the fundamental law which controls the relations of the infinitesimal atoms and molecules of matter, molecules being thought of as miniature solar systems in which the constituent atoms are held in equilibrium on the same principle of electrical attraction and repulsion which regulates the movements of enormous celestial orbs in their orbits.

Be this as it may, the fact remains that the chemist gains his conception of the properties of matter by collating thousands of *facts*, the fruits of experiment, while the astronomer and physicist maintain a very different conception through having approached the subject from the standpoint of a preconceived hypothesis of a universal uniformly-acting energy of attraction between the particles of matter. If the two views cannot be reconciled, it is certain that hypothesis must eventually be conquered by experimental facts. The phenomena of chemical affinity and the hypothesis of Newton have never been reconciled. I have no hope of the possibility of such a reconciliation. Therefore I take my stand with the chemist and his method, in contrast with that of the theorizing astronomer and physicist.

Respectfully,
FRANK ALLABEN.

PART V.

THE ZODIACAL LIGHT.

The cause and nature of the zodiacal light have never been explained in a satisfactory way by Newtonian-Copernican astronomers, although this is one of the puzzles to which ingenious investigators have addressed themselves since the days of Kepler. But the moment we assume as true the Tychonic hypothesis of the celestial movements, this difficult problem receives a solution so simple and obvious that it becomes in turn a powerful argument in favor of the Tychonic theory.

The zodiacal light has the appearance of a huge, faintly luminous cloud of attenuated matter, which attends the sun in his apparent daily circuit of the earth. Just before daybreak it appears in the eastern sky, a nebulous pyramid of light, with its base resting upon the horizon and the apex sometimes extended upwards for ninety degrees, or to the zenith of the heavens. The sun rises at the centre of the base. After sundown it appears in the western sky, the point where the sun has disappeared behind the horizon being the centre of its base, from which it slants to an apex often extending upward for ninety degrees. The ninety degrees of light which precede the sun above the eastern horizon, with the ninety degrees of light which trail after him above the western horizon, constitute a luminous cloud, of which the sun is the centre, shaped like a double-convex lens and one hundred and eighty degrees long, reaching half-way around the heavens, or from the zenith to the nadir. At times this light has been visible even at midnight, when the sun had reached the meridian at the opposite side of the globe. In a clear atmosphere observers in the tropics have also seen it extending for one hundred and eighty degrees, from the eastern to the western horizon, thus forming a luminous band about the earth in the path of the sun's apparent daily circuit. Says Prof. C. Michie Smith ("Encyclopædia Britannica," 9th edition):

"Various observations show that at times the base, at an elongation of about twenty degrees, may have a width of from twenty-five degrees to thirty degrees, while at an elongation of sixty degrees the breadth is frequently as much as twenty degrees, but usually much less. The distance of the vortex from the sun frequently exceeds ninety degrees, and Mr. Liais and others have recorded cases when the light has been traced completely around from the western to the eastern horizon. This is very uncommon; but it is not at all rare to find the light stretching nearly to the meridian three hours after sunset, and several observers have recorded the existence of a bright patch of light almost opposite to the position of the sun. This is known as the *Gegenschein*, and though it has been seen comparatively seldom, its existence must be accepted as proved; for its position has been determined by actual measurement by several astronomers, and their results agree with quite as great closeness as can be expected in the determination of the position of such an object. A lengthened series of observations was made on the zodiacal light by the Rev. G. Jones, chaplain of the United States steam frigate "Mississippi," in the China and Japan seas in 1855. He charted the apparent position of the cone of light on a large number of nights and mornings, and came to the somewhat startling conclusion that his observations could be explained only by supposing the existence of a nebulous ring around the earth within the orbit of the moon. He recorded that twice near 23 degrees 28 minutes north latitude, with the sun at the opposite solstice, he had seen 'the extraordinary spectacle of the zodiacal light simultaneously at both the east and west horizons from eleven to one o'clock for several nights in succession!' On reading this statement, Baron Humboldt communicated to the *Monatsberichte d. kön preuss. Akad. d. Wiss.* some unpublished observations of his own on a similar phenomenon. These were to the effect that on the 17th and 18th of March the light was very bright in the west, and 'we constantly perceived in the east (and this is beyond doubt a very striking phenomenon) a whitish light which was also of a pyramidal form. The latter augmented the brightness of the sky in a very striking manner.'"

According to the Tychonic theory the sun encircles the earth daily, while at the same time moving between the celestial tropics on semi-annual journeys north and south. Beginning at the winter solstice, when he is directly overhead at the tropic of Capricorn, his daily circuit around the earth, modified by his movement north, follows the path of an enormous spiral about the earth. During the following six months he describes a return spiral. The zodiacal light appears in attendance upon the sun in the track of this spiral between the tropics. If this apparent motion of the sun represents his real movement, as Tychonic theory supposes, then the zodiacal light is readily explained as a nebulous cloud of matter radiated from the sun—the extension of the sun's corona. But if the apparent daily circuit of the sun is the result of the diurnal rotation of the earth upon its axis, while the ecliptic indicates the path of the earth in its orbit around the sun, then the belting of the entire earth by the zodiacal light, as when Chaplain Jones observed it for 180 degrees at a time when the sun was crossing the meridian on the opposite side of the earth, presents a difficulty of a most puzzling character.

Among the Arabians this phenomenon was known as the "false dawn." Kepler observed the zodiacal light, at the same time suggesting that it might be the atmosphere of the sun. This view generally prevailed until Laplace proved it untenable, although Cassini had, about 1683, suggested another explanation. The hypothesis of Kepler, which had gained currency, Laplace disposed of by calling attention to the fact that no atmosphere could rotate with the sun if extending beyond the distance where centrifugal force is balanced by gravity, whereas the zodiacal light extends far beyond this distance.

The observation of the light, as a band entirely encircling the earth, is absolutely fatal to any Copernican hypothesis which conceives of it as an atmosphere which attends the sun, for how can such an atmosphere encircle the earth unless the sun actually circumscribes the earth in a daily orbit, leaving illuminated particles streaming after him?

Cassini explained the zodiacal light as a luminous ring around the sun, nearly in the plane of his equator, somewhat like the ring of Saturn. But on the basis of Newtonian-Copernican conceptions, it is plain such a ring must extend around the sun outside the earth's alleged annual orbit, for the zodiacal light is seen on each side of the sun in the plain of the ecliptic.

We might, indeed, conceive of a nebulous ring as a circle about the sun, lying in the plane of the ecliptic, the diameter of which is greater than the distance between the earth and sun; but all observations discountenance this view and go to show that we cannot well avoid the conclusion that the zodiacal light is an extension of that radiation from the sun, whatever may be its nature, which we style the corona. "The general opinion respecting the zodiacal light at the present day is that it forms the outer part of the solar corona, so that if the light of the sun could be for a time obliterated without rendering his appendages invisible, we should see the corona," wrote the late Professor R. A. Proctor, "merging gradually into the faint glow of the zodiacal light."

The corona may be popularly described as a vast halo of white light surrounding the sun, becoming visible during a total eclipse and presenting the appearance of rays of light, or of incandescent matter, streaming from the sun in every direction. Photography and the spectroscope have since

1860 shown the corona to be a true appendage of the sun, of a complex nature. The testimony of the spectroscope is to the effect that it contains incandescent vapors, together with particles of matter which reflect sunlight.

A periodicity has been observed in connection with the zodiacal light, which is much more conspicuous for a series of several years than for a succeeding series. While this period cannot certainly be stated, on account of the comparative poverty of systematic observations, yet it probably depends upon the eleven-year solar cycle, which is characterized by a maxima and minima of sun-spots, and probably is an effect of the fluctuations of the corona during this period. For it has been well established that the appearance of the corona bears a remarkable resemblance to the zodiacal light during the period of minimum sun-spots, but takes on another appearance during the period of maximum sun-spots. The appearance of the corona at the time of the total eclipse of July, 1878, when the sun-spots were at their lowest ebb, has been thus described:

"There was seen, as the groundwork of the corona, a ring of pearly light, nebulous to the eye, but shown by telescopes and in photographs to have a fibrous texture, as if made up of tufts of fine hairs. North and south, a series of short, vivid, electrical-looking flame-brushes diverged with conspicuous regularity from each of the solar poles . . . .

"But the leading, and a truly amazing, characteristic of the phenomenon was formed by two vast, faintly luminous *wings* of light, expanded on either side of the sun in the direction of the ecliptic. These were missed by very few careful onlookers; but the extent assigned to them varied with skill in, and facilities for seeing. By far the most striking observations were made by Newcomb at Separation (Wyoming), by Cleveland Abbe from the shoulder of Pike's Peak, and by Langley at its summit, an elevation of 14,100 feet above the sea. Never before had an eclipse been viewed from anything approaching that altitude, or under so translucent a sky. A proof of the great reduction in atmospheric glare was afforded by the perceptibility of the corona for above four minutes after totality was over. During the 165 seconds of its duration, moreover, the remarkable streamers above alluded to continued 'persistently visible,' stretching away right and left of the sun to a distance of at least ten million miles! One branch was traced over an apparent extent of fully twelve lunar diameters, without sign of a definite termination having been reached; and there were no grounds for supposing the other more restricted. The axis of the longest ray was found to coincide exactly, so far as could be judged, with the ecliptic. Pale cross-beams were seen by Young and Abbe.

"The resemblance to the zodiacal light was striking; and a community of origin between that enigmatical member of our system and the corona was irresistibly suggested. We should, indeed, expect to see, under such exceptionally favorable atmospheric conditions as Professor Langley enjoyed on Pike's Peak, the *roots* of the zodiacal light presenting near the sun just such an appearance as he witnessed; but we can imagine no reason why their visibility should be associated with a low state of solar activity. Nevertheless this seems to be the case with the streamers which astonished astronomers in 1878. For in August, 1867, when similar equatorial emanations, accompanied by similar symptoms of polar excitement, were described and pictured by Grosch of the Santiago Observatory, sun-spots were at a minimum; while the corona of 1715, which appears from the record of it by Roger Cotes to have been of the same type, preceded by three years the ensuing maximum." *

But while it is probably true that the type of corona described above and the zodiacal light are especially conspicuous when sun-spots are at their minimum, it is by no means settled as yet that this is the time of "a low state of solar activity," in the sense intended. The reverse may be the case, for a high state of solar *disturbance*, such as characterizes the period when sun-spots are at their maximum, may after all be the time of a low state of solar *radiation*. In so far as meteorological conditions on the earth appear to fluctuate with the solar extremes of the eleven-year cycle, atmospheric disturbances, with heavy rainfall, seem to attend a maximum of sun-spots, whereas extra heat and dry weather coincide with a minimum of sun-spots. Therefore radiation may reach its maximum at the time of least solar disturbance. In the same way, while unusual electrical storms and other kindred phenomena on the earth are undoubtedly special effects of the solar disturbances when sun-spots are numerous, yet electro-magnetic radiation from the sun may be most powerful when the equilibrium is not so disturbed, while it may be that the stress thus produced is periodically relieved at the time of greatest disturbance.

The observations of the corona during eclipses since 1878 all confirm the supposition that the wing-like projections of the corona resembling the zodiacal light appear periodically, at the time when sun-spots are at their minimum. The other type, prevalent during the period when sun-spots are at their maximum, is that of a very large corona with star-like beams of rays in every direction. This type having been observed in 1871, and the other in 1878, great interest was aroused at the time of the eclipse of 1882, the period of another maximum of sun-spots, to learn whether a periodical recurrence of the type of 1871 would be disclosed. The result has been thus described:

"The year 1882 was one of numerous sun-spots. On the eve of the eclipse twenty-three separate maculæ [sun-spots] were counted. If there were any truth in the theory which connected coronal forms with fluctuations in solar activity, it might be anticipated that the vast ecliptical expansions and polar 'brushes' of 1878 would be found replaced by the star-like structure of 1871. This expectation was literally fulfilled. No zodiacal streamers were to be seen. The universal failure to perceive them, after express search in a sky of the most transparent purity, justifies the emphatic assertion that *they were not there.* Instead, the type of corona observed in India eleven years earlier, was reproduced, with its shining aigrettes, complex texture, and brilliant radiated aspect." *

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* "A Popular History of Astronomy during the Nineteenth Century." By Agnes M. Clerk, 3d edition, 1893, pp. 219-21.

As we have seen, the only rational assignment of position to a zodiacal light which sometimes circumscribes the earth, consistent with Copernican theory, is that of a nebulous circle in the plane of the ecliptic, but outside the earth's orbit. One of the most plausible hypotheses was that of a mass of meteors, or other diminutive bodies, revolving about the sun in such an orbit. This was the view maintained in the "Encyclopædia Britannica" some years ago by Professor C. Michie Smith, and accepted by most astronomers as the only way out of the difficulty. The hypothesis of Chaplain Jones, of a luminous band around the earth within the orbit of the moon, Professor Smith dismissed as utterly untenable, as follows:

"The theory that it is due to a ring of small bodies surrounding the earth seems to be entirely negatived, as pointed out by Proctor and others, by several of its features. The best observations leave no room for the parallactic displacement which would be observed if there were such a ring around the earth, and the absence of a large part of the luminous circle on ordinary occasions would be inexplicable on any such hypothesis."

He goes on to describe what he considers the correct hypothesis:

"There can therefore be very little doubt that we must look for the cause of the light to the existence of a mass of small bodies moving in orbits around the sun, and that, as shown by the polarization and the spectrum, the light is chiefly, if not entirely, reflected sunlight. To account for all the observations, Proctor has shown that the bodies must travel in orbits of considerable eccentricity, carrying them far beyond the limits of what we may term the zodiacal disk. Under these conditions the constitution of the disk would become variable within exceedingly wide limits, and all the recorded variations might be fairly explained. The appearance of a complete arch, as seen by Liais and others, would indicate an extension far beyond the earth's orbit."

This hypothesis, absolutely vital to Copernican theory as it would seem to be, has nevertheless, as we have remarked above, been discountenanced by the accumulation of observational evidence since the above words were written. The hypothesis which we must now consider as pretty well established is that to which Professor Smith referred as follows:

"Olbers long ago suggested that the corona was the brightest part of the zodiacal light, and there is nothing in recent observations to contradict this view, for all observations go to show that the outer corona has no definite boundary, but shades off imperceptibly and becomes invisible at a great distance from the sun. Dr. Huggins, while holding that the corona is most probably due to the ceaseless outflow of extremely minute particles from the sun, thinks it not improbable that the zodiacal light may be in some way connected with this outflow. Dr. Siemens, when discussing his theory of the conservation of solar energy, sought for an explanation of the zodiacal light in the dust which he supposed to be ejected from equatorial regions, rendered luminous partly by reflected sunlight, partly by phosphorescence, and partly by electrical action."

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* *Ibid.*, p. 223.

The testimony of recent eclipses forces us to agree with Olbers, Dr. Huggins and Dr. Siemens that the zodiacal light is an extension of the solar corona ; to agree with Dr. Huggins and Dr. Siemens that both corona and zodiacal light are caused by the expulsion from the sun of minute particles of matter, and to agree with Dr. Siemens that this expulsion is an electrical phenomenon. Yet to so explain the zodiacal light, while at the same time forced to conceive of it as a band sometimes encircling the earth, is to aim a powerful blow at Copernican theory, urging us toward the Tychonic theory, which repudiates the hypothesis of a diurnal rotation of the earth, substituting that of an actual daily revolution of the sun around the earth. It is not a matter of wonder, therefore, that Copernican theorists have well-nigh exhausted ingenuity to invent a hypothesis which is more consistent with Copernican theory. Thus, after viewing the eclipse of 1878, Professor Abbe advanced the hypothesis that the coronal rays are not caused by matter emanating from the sun, but by meteorites encircling the sun. His view and the considerations which discredit it are thus summarized in the volume of Agnes H. Clerke:

"Professor Cleveland Abbe was fully persuaded that the long rays carefully observed by him from Pike's Peak were nothing else than streams of meteorites rushing towards or from perihelion ; and it is quite certain that the solar neighborhood must be crowded with such bodies. But there are no grounds for supposing that they affect the ecliptic more than any other of the infinite number of planes passing through the sun's centre. On the contrary, everything we know leads us to believe that meteorites, like their cometary allies, yield no obedience to the *rules of the road* which bind the planets, but travel in either direction indifferently, and in paths inclined at any angle to the fundamental plane of our system. Besides, the peculiar structure at the base of the streamers displayed in the photographs, the curved rays meeting in pointed arches like Gothic windows, the visible upspringing tendency, the filamentous texture, speak unmistakably of the action of forces proceeding *from* the sun, not of extraneous matter circling around him.

"It may be asked what possible relation can exist between the zodiacal plane and the sun's internal activity? For it is a remarkable fact that to this approximately, and not to the level of the solar equator, the streamers conformed. We are acquainted with no such relation ; but it may be remarked that the coronal axis of symmetry has frequently been observed during eclipses to be inclined at an appreciable angle to the solar axis of rotation, and the corresponding 'magnetic equator' might quite conceivably be the scene of emanations induced by some form of electrical repulsion." *

All attempts to account for the corona as an atmosphere of the sun have been abandoned. Another hypothesis was that it was due to an atmosphere of the moon; but apart from the serious question whether the moon has any atmosphere to speak of, this explanation was disproved by success in photographing the corona when there was no eclipse, and the moon and its supposititious atmosphere were far removed from the vicinity of the sun. The hypothesis has also been advanced that the corona might be an effect produced by the atmosphere of the earth; but, in the words of Agnes M. Clerke, "The plain fact, that our atmosphere acts rather as a veil to hide the coronal radiance than as the medium through which it is visually formed, emerges from the records of innumerable observations." Professor Schaeberle, taking the view that the corona represents matter expelled from the sun, has yet attempted to explain the phenomenon on a strictly mechanical basis. We quote Miss Clerke's summary of his hypothesis and the grounds which compel its rejection:

"The problem of deducing the real shape of the corona, as it exists in space, from its projection upon a flat surface hung up in the sky for our inspection during total eclipses, was first grappled with in its entirety by Professor J. M. Schaeberle of the Lick Observatory. His resulting 'mechanical theory' makes the corona to consist, in its physical reality, of streams of matter shot out with great velocity from the spot-zones by forces acting perpendicularly to the sun's surface. The rays thus formed are not, however, straight. The particles composing them, since they bring the rotational speed of a smaller into a larger sphere, lag behind as they ascend, and eventually return to the sun, after describing sections of extremely elongated ellipses. That is, unless their initial velocity equals or exceeds the critical rate of 383 miles a second, by which they would be finally driven off into space. This state of things is perennial; but the visual effect changes with the point of view. 'According as the observer is above, below, or in the plane of the sun's equator,' our author remarks, 'the perspective overlapping and interlacing of the two sets of streamers cause the observed apparent variations in the type of the corona.' The corona, then, is always essentially the same, and only certain limited portions of the solar surface are concerned in its production. What seems like polar emanations are really, on this hypothesis, the tips of zonal streamers issuing from behind the moon. These speculative conclusions were strikingly illustrated by Professor Schaeberle's device of photographing, in various positions, a model globe bristling with properly arranged needles. But the objection immediately occurs that if

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*"History of Astronomy," 3d edition, pp. 221-2.

coronal shapes depended only upon the situation of the earth with regard to the sun's equator, they should be subject to an annual periodicity. The same type should recur at the same time of year. This, however, is far from being the case. 'Winged' coronas have been recorded in May (at Cotes' eclipse of 1715), August, July, December and January; radiated coronas in July, December, May and August. Nothing could well be more unlike the corona of December 21, 1870, than the corona of December 22, 1889. Yet according to the 'mechanical theory' they ought to have been perfectly similar. The agreement with the spot-cycle, on the contrary, of the physical changes in this beautiful if commonly hidden solar appendage appear[s] so far unfailing; although optical changes, such as those pointed out by Professor Schaeberle, are doubtless added." *

The same writer approvingly mentions the more tenable electrical theory of Professor Bigelow and gives a summary of the ascertained facts respecting the sun's corona, as follows:

"Professor Bigelow's theory of the corona goes deep into the nature of things. He indeed claims for it no more than an abstract character; but it is a case in which correct mathematical construction is scarcely separable from physical truth. By an able discussion of the beautiful American photographs of January 1, 1889, he showed a marked coincidence between the distinctive coronal forms and the calculated effects of a repulsive force acting according to the laws of electric potential. Finely subdivided matter is, on this view, expelled from the sun along lines of force emanating from points near his poles, and tends to accumulate at 'equipotential surfaces.' 'The straight polar rays of high tension carry the lightest substances, as hydrogen, meteoric matter, débris of comets, and other coronal material, away from the sun, and they become soon invisible by dispersion.' The strong quadrilateral rays, conspicuous at periods of great solar activity, come next in strength of potential, which, however, falls off rapidly outward. 'The explanation of the long equatorial wings, with absence of well-marked quadrilaterals, is that they are due to the closing of the lines of force about the equator. The re-entrance of these lines forms along the equator, the place of zero potential, a sort of pocket or receptacle wherein the coronal matter is gradually carried by the forces, accumulated and retained as a solar accompaniment.' The appurtenance thus formed and fed may, Professor Bigelow thinks, be no other than the mysterious zodiacal light. The entire theory is, however, expressly left floating in the analytical empyrean; it is too soon to attempt its establishment upon a secure physical basis. 'In deference,' its deviser says, 'to the doubt that free electricity can exist at such temperatures as prevail on the sun's surface,' he has avoided 'speaking of the apparent coronal structure as a phenomenon of electricity.' Its details, if it were, he limits himself to pointing out, would be just what they

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* *Ibid.*, pp. 237-8.

are. Hence the great interest and value of their precise photographic registration.

"Summing up what we have learned about the corona during some fifty minutes of scrutiny in as many years, we may state, to begin with, that it is *not* a solar atmosphere. It does not gravitate upon the sun's surface and share his rotation, as our air gravitates upon and shares the rotation of the earth; and this for the simple reason that there is no visible growth of pressure downwards (such as the spectroscope would infallibly give notice of) in its gaseous constituents; whereas under the sole influence of the sun's attractive power, their density should be multiplied many million times in the descent through a mere fraction of their actual depth.

"The corona is properly described as a solar appendage; and may be conjecturally defined as matter in a perpetual state of efflux from, and influx to our great luminary, under the stress of electrical repulsion in one direction, and of gravity in the other. Its constitution is of a composite character. It is partly made up of self-luminous gases, chiefly hydrogen, and the unknown substance named coronium giving the green ray '1474;' partly of white-hot solid or liquid particles, shining with continuous light, both reflected and original. There is a probability amounting almost to certainty that it is affected both in shape and constitution by the periodic ebb and flow of solar activity, its low-tide form being winged, its high-tide form stellate; while the rays emitted by the gases contained in it fade, and the continuous spectrum brightens, at times of minimum sun-spots, as if by a fall of temperature producing, on the one hand, a decline in luminosity of the incandescent materials existing near the sun, and, on the other, a condensation of vapors previously invisible into compact particles of some reflective capacity. The coronal materials must be of inconceivable tenuity, since comets cut their way through them without experiencing sensible retardation. Not even Mr. Crooke's vacua can give an idea of the rarefaction which this implies. Yet the observed luminous effects may not in reality bear witness contradictory of it. One solitary molecule in each cubic inch of space might, in Professor Young's opinion, produce them; while in the same volume of ordinary air at the sea-level, the molecules number (according to Mr. Johnstone Stoney) 20,000 trillions!" *

While the fruits of the observations of the total eclipse of May 28, 1900, a time of minimum sun-spots, are scarcely accessible as yet, what has been so far announced bears witness in the same direction. The winged form of corona was in evidence as expected, thus finally settling the question of its periodic recurrence during the period of minimum sun-spots. Again M. Perrotin, Director of the Observatory of Nice, has called the attention of the Academie des Sciences, of Paris, to the coincidence between the brightness of the zodiacal light, in April and May, 1900, in a part of the sky where it is scarcely visible, with the form and intensity of the corona as revealed in the eclipse of May 28. Finally, despite the unusual intensity of the corona on this occasion, measurements of its heat with that most delicate invention of Professor Langley, the bolometer, evidently show that the corona is not a hot body, thus confirming the theory of electrical expulsion of cosmical matter from the sun, as formerly advocated by Professor W. A. Norton, of Yale College, by Dr. Siemens, and latterly by Professor Bigelow, of Washington. We here cite from the fourth edition of his work the conjecture of Professor Norton respecting the zodiacal light, which bids fair to become established with the accumulation of observational evidence :

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* *Ibid.*, pp. 238–40.

"We may regard the whole mass as made up of the streams of particles which we have recognized as continually in the act of flowing away from the sun, under the operation of a force of solar repulsion ; or, in other words, that it is the indefinite continuation of the corona observed in total eclipses of the sun, with its attendant streamers. Upon this view it should appear elongated, like the faint outer boundary of the corona, in the plane of the sun's equator ; and this elongation may be attributed to a more copious discharge of the photospheric matter from the equatorial than from the polar regions of the sun. Or we may conceive, in accordance with the theoretical views of the probable condition of the sun's photosphere that have been presented, that the discharges may take place from the tops of the photospheric columns, in the direction of their prolongation. All such discharged particles would thus receive a projectile velocity oblique to the sun's surface, and toward the plane of the equator, and, being subsequently repelled by the sun, would move away into space in hyperbolic orbits, convex toward the sun. As a necessary consequence, there would be an augmentation of the quantity of escaping matter in the plane of the sun's equator, and an elongation of the visible portion in this plane. The light may vary in brightness from one year to another, with the varying activity of discharge from the sun's surface." *

In order that the reader may have the results of observation quite completely before him, we add here Professor Norton's summary of Chaplain Jones' observations:

"The most valuable series of observations extant on the zodiacal light are those which were made in the years 1853-4-5, at various latitudes, from forty-one degrees, forty-nine minutes N. to fifty-three degrees, twenty-eight minutes S, by Chaplain Jones, of the U. S. Navy ; and by the same ob-

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* "A Treatise on Astronomy, Spherical and Physical: with Astronomical Problems, and Solar, Lunar, and Other Astronomical Tables. For the Use of Colleges and Scientific Schools." By William A. Norton, M. A., Professor of Civil Engineering in Yale College. Fourth edition. New York: 1878, p. 173. His electrical-expulsion theory of the corona Professor Norton maintained as early as 1845, in the second edition of his "Treatise on Astronomy."

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[illegible] the earth [illegible] the sun [illegible] an emission of matter from the sun is [illegible] accounted for by [illegible] as we have before said. But [illegible] American Journal? Professor [illegible] we can conceive of [illegible] the ap[illegible] and peculiar [illegible]. But by [illegible] repulsion, whereas [illegible] supposing that the earth's atmo-

[illegible]

sphere is simply a veil which obscures the phenomenon, rather than an element in its production.

An English correspondent [Sir W. J.], conceding the plausibility of some of the arguments against the postulate of the diurnal rotation of the earth which are presented in the pamphlet, "The Earth Stands Fast," observes on the other hand: "The one difficulty in the way of the theory of the sun going around the earth is, that as it must travel at the rate of many millions of miles in twenty-four hours, it ought to leave in its track a trail of fire; but perhaps that is obscured by the tremendous distance the sun is from the earth." When we reflect that the sun is an electro-magnetic centre of radiation, we must admit that this point is well taken, and we now point to the zodiacal light as the evidence that the sun *does* "leave in its track a trail of fire," while we suppose that, but for our atmosphere, the splendor of this phenomenon would far exceed its present appearance.

But it may be objected that, according to Tychonic theory, the moon also describes a daily orbit about the earth, and while this is vastly smaller than the orbit of the sun, and the moon's velocity therefore proportionately less than that of the sun, yet, since the moon is also in measure electro-magnetic, something like the zodiacal light should be observed in the case of the moon. The reply is that such a phenomenon has probably been observed in the case of the moon. We cite on this score from the article of Professor C. Michie Smith, already referred to:

"*The Moon's Zodiacal Light.*—Several observers have recorded observations which appeared to show that the moon produced an appearance very similar to that of the zodiacal light. Piazzi Smyth, however, when observing on the Peak of Teneriffe, saw this appearance and showed by actual measurement that the glow seen before moonrise does not lie near the ecliptic, but is nearly vertical, and is due simply to refraction in the earth's atmosphere. This explanation will hardly account for an interesting observation made by Mr. L. Trouvelot, which if repeated would require to be very carefully investigated. On a night when the zodiacal light was very bright and there were magnetic disturbances followed by an auroral display, but when no aurora was actually visible, he saw a conical light rising obliquely from the top of the roof of a building behind which the moon, then about fifteen degrees or twenty degrees above the horizon, was concealed. The axis of the light coincided nearly with the ecliptic and the light could be traced on both sides of the moon, when the moon itself was concealed. The whole of the circumstances led Mr. Trouvelot to conclude that this light and the zodiacal light were phenomena of the same order, while this and other observations, he considered, rendered it probable that there was some connection between the zodiacal light and auroras."

In this connection we cannot avoid calling attention to the remarkable daily oscillations of the magnetic needle everywhere upon the globe, one set of perturbations being caused by the electro-magnetic influence of the sun, and the other by that of the moon, as these orbs make their apparent daily circuits of the earth. This is readily accounted for on the basis of Tychonic theory, provided that the zodiacal light is an evidence that sun and moon, in actual daily circuits of the earth, expel molecules from their substance which are radiated in space in every direction. Probably at the same time they also receive an influx of electrified matter, which is in an opposite state of electrification and thus attracted to their mass. No doubt this daily circuit of the celestial orbs induces electrical currents which circulate about the earth in the equatorial regions, in the earth's crust and in the upper atmospheric regions. A magnet produced by such currents would lie with its axis of polarity at right angles to them, and the earth is such a magnet, with its axis of polarity lying from north to south. We believe that the Tychonic theory, worked out on the assumption of universal electrical attractions or repulsions, would permit the correlation of all celestial and terrestrial phenomena of the physical universe as diverse effects of the operation of one fundamental law. Certainly the attempt of scientists to reach such a result by means of Newtonian-Copernican theory, worked out on the assumption of universal gravitation, has signally failed.

PART VI.

NORTON'S THEORY OF SUN-SPOTS.

The discovery of apparent spots on the sun's surface was made by Galileo and Fabricius in 1610. Galileo considered them clouds in a solar atmosphere which eclipsed portions of the sun's surface, while Simon Marius accounted for them as slag, the cinder remains of solar combustion. Canon John Tarde, however, in 1620 advanced the hypothesis that they were due to the transit of planets across the sun, this view being also championed by Father Scheiner and William Gascoigne. Derham, in 1711, maintained that the so-called sun-spots were solar volcanic eruptions. D. Cassini, in 1671, and Lalande, in 1776, thought the spots rocky elevations on the sun's surface, over which occurred the ebb and flow of a luminous ocean.

The view which has long prevailed, that these appearances represent enormous excavations in the sun's photosphere, or outer shell, was suggested by some of the observations of Father Scheiner, and was successively advocated by Leonard Rost, Lahire, J. Cassini, and Pastor Schülan. It only gained general credence, however, through the publication, in 1774, by Professor Alexander Wilson, of the University of Glasgow, of a paper showing by geometrical principles that the "spots" presented precisely the changing appearances, at different stages of the sun's axial rotation, which deep excavations should present. But at the same time he advanced the hypothesis that the sun consists of a dark globe, solid or liquid, surrounded by one or more incandescent envelopes of vaporous matter, which are the actual sources of solar light and heat. Herschel amplified this speculation, even suggesting that the dark body of the sun, protected by heavy clouds from its outer fiery envelope, might be inhabited. This conception prevailed quite generally until about 1860, when the revelations of the spectroscope, while confirming the supposition that the sun is enveloped in luminous vapors, thousands of miles in depth, indicated that the sun itself is a fiery globe even hotter than the surrounding metallic vapors. The spectroscopic and photographic observations of the last forty years have, in fact, led to a conception of the constitution of the sun which may be summarized as follows:

1. The main body of the sun is an enormous energy-radiating mass of matter, the temperature of which is phenomenally high as measured by the highest temperature known on the earth. Since it gives a continuous spectrum, this mass must be either in a solid or liquid state, or else consists of highly-compressed gaseous matter. Its mobility indicates that the mass is gaseous, although the density of the sun computed under Newtonian-Copernican theory requires us to conceive of a gaseous conglomeration under such pressure that its consistency is about that of honey. There are probably constant movements of this spherical mass, possibly from centre to circumference, by means of huge convection currents. This view supposes that the hotter matter in the interior rushes to the sun's surface, where it is somewhat cooled by the radiation of a portion of its energy into space, while from the surface the cooler matter rushes downward.

2. The sun's visible surface, called the *photosphere*, is now thought to consist of masses of incandescent clouds. It apparently is made up of intensely bright "granules," one hundred miles or more in diameter, floating in a darker medium. Although these "granules" constitute but one-fifth of the photosphere, or visible bright surface of the sun, yet Professor Langley concludes that from them is given off three-fourths of the light radiated from the sun. It is supposed that the "granules" are the upper extremities of ascending columns of hot matter from the interior of the sun, while the darker formations surrounding them are the bases of descending columns of cooler matter. The sun-spots are by many supposed to be depressions, if not actual rents, in the photosphere.

3. Surrounding the "photosphere" of the sun is a formation with an average diameter of about 5000 miles and the appearance of a scarlet sheet of flame. It is called the *chromosphere.*

4. A total eclipse of the sun renders visible the so-called "prominences," which appear to be extensions of the chromosphere—red flames which leap up at times to a height one-fourth the sun's diameter, or 200,000 miles above the sun's surface.

5. A total eclipse also reveals a silvery halo of streaming light all about the sun, the rays of which reach out far beyond photosphere, chromosphere, and even the rose-colored "prominences." The rays or streamers of coronal light are often visible millions of miles from the sun, the degree of luminosity gradually decreasing from the sun's surface outward.

Nearly one-half of all the chemical elements known on the earth have, by spectroscopic analysis, been shown to be constituents of the sun's mass, while it is possible that the rest may eventually be detected. Bearing this in mind, a simple and natural explanation of many of the different solar phenomena mentioned above appears when we conceive of the sun as a globular mass of superlatively-heated matter of different kinds, reduced by the extreme heat to the gaseous state. In the photosphere we have the outer layer of this seething mass, itself intensely hot, if cooler than the interior, and communicating a portion of its energy-vibrations to the surrounding ether. In the chromosphere we have the vaporous flames which would naturally rise from the surface of such a mass, while the "prominences" are unusually large flames. In the corona we have incandescent vaporous matter which is expelled into space, a portion of which falls back into the sun.

Spectroscopic analysis, in so far as it can be applied, bears out this supposition. Since the photosphere gives a continuous spectrum, there is no direct indication of the kind of matter of which the sun's bulk is composed; but against the background of this spectrum the gases enveloping the sun register themselves by means of dark lines, while it is a natural inference that those gases have issued from the sun's substance and indicate its nature. The rose-colored chromosphere and prominences are thus shown to consist of hydrogen, helium, calcium, iron, sodium, magnesium, barium, titanium, and other elements in the form of glowing gases. The heavier of these elements are present with the lighter ones in the chromosphere and "flame-prominences," while only the latter, hydrogen, helium, calcium, and certain unknown elements, appear in the upper "cloud-prominences." The corona contains a large proportion of luminous gases, including hydrogen and an element called coronium, which is probably lighter than hydrogen.

Thus we have before us, in brief, a rough sketch of the prevalent view of the sun's constitution, while the very difficult problem as to the forces at work to produce these results at once presents itself. No satisfactory explanation of all the phenomena has been forthcoming, upon the assumption that gravitation is the energy in question, for a repulsive force as remarkable as the attractive force is exhibited by the sun, and it is obvious that a rational explanation must account for the one as well as for the other. Under these circumstances it would seem most natural to turn for an explanation to electro-magnetic energy, which is experimentally known to produce both attractive and repulsive phenomena. Most astronomers and physicists, however, have been slow to look in this direction, being reluctant to abandon the convenient device of referring everything to Newton's law, or to join with it recognition of another cosmical force, the nature and laws of which have not yet been fully investigated. Nevertheless, the accumulation of observational evidence is gradually forcing the most conservative to substitute electro-magnetic for gravitational solutions of many physical problems, and it is the conviction of the present writers that this process will continue until a complete revolution in cosmical theory has been effected. We therefore recall the electrical theory of solar activity proposed by Professor William A. Norton, many years ago, in order to inquire whether the testimony of recent observations tends to justify his attempt to reach a solution founded in electrodynamics.

The view of solar constitution upon which Professor Norton proceeded, as the premise for the theory presented in the fourth edition of his "Treatise on Astronomy," is revealed by a few quotations: He held that "the dark spots on the sun are depressions below the luminous surface." He recognized that "the solar spots are mostly confined to two zones parallel to the equator, and extending from five degrees to thirty-five degrees of latitude. Beyond thirty-five degrees they are rarely seen, and in the polar regions never. The actual equator is also seldom, if ever, visited by spots. They are most abundant toward the middle of the spot-belts, and prevail more in the northern than in the southern hemisphere." He declared that "the motions of the spots are accounted for, in all their circumstances, by supposing that the sun has a motion of rotation from west to east, around an axis nearly perpendicular to the plane of the ecliptic; and that the spots are portions of the solid body of the sun." On the question of periodicity he remarked that "Professor Wolf, of Zurich, by a careful discussion of the observations of the solar spots made during the last one hundred years, has determined that the period of the spots has varied, during this interval, from eight to sixteen years, and that its mean value has been 11.11 years." In the rose-colored prominences he saw "luminous masses connected with the sun, and elevated above the photosphere." The coronal streamers he thought had "the appearance of radiations of luminous matter, in directions perpendicular to the sun's surface." His conclusion respecting the corona, remarkably vindicated as it has been by subsequent observations, was as follows:

"The corona is supposed by Sir John Herschel, and other astronomers, to be a gaseous solar atmosphere, extending above the sun's photosphere; but its vast extent seems to be fatal to this explanation. Upon no reasonable supposition that can be made with regard to the effects of the sun's heat in expanding such an atmosphere, can it be supposed to have sufficient density to reflect a sensible amount of light, beyond a few thousand miles from the body of the sun [whereas "observations made with the polariscope have establishd that the light of the corona and streamers is in part reflected light."] The natural indications of the phenomena are that the corona consists of luminous matter streaming off from the sun into space, and at the same time that the appearance of distinct radiations arises from an inequality of emanation from different parts of the sun's surface. The elliptical form of the corona indicates that the emission of luminous matter is most abundant from the equatorial regions. It has been suggested that the radiated appearance of the corona may result from a partial interception of the sun's light by clouds floating in the sun's atmosphere; but the course of the rays which pass unobstructedly through the spaces between the clouds could not be recognized unless they encounter matter of sufficient density to reflect a sensible quantity of light to the eye, and such matter cannot extend to a distance of more than a million of miles from the sun, unless there are material emanations proceeding from the sun. We can only avoid this conclusion by assuming that there is a dense mass of meteoric bodies, or of cosmical matter, revolving around the sun within this distance. It is maintained by some astronomers that the corona and streamers are phenomena of diffraction, resulting from the passage of the sun's light near the borders of the moon. But, upon this explanation there ought to be certain attendant phenomena of variegated colors which are not in reality seen." *

Upon the basis given Norton presented the following theory:

"The careful scrutiny and assiduous study, by several astronomers, of all the phenomena observable on the surface of the sun for a number of years past, has led to the following important discovery:

"*The sun's spots are for the most part developed by, or in some way connected with, the operation of a physical agency exerted by the planets upon the photosphere.* This remarkable fact has been conclusively established by the observations of Schwabe, Carrington, Secchi, and others; and especially by the detailed discussion to which all the reliable observations upon the spots, made during the last one hundred years, have been subjected by Professor Wolf, of Zurich. The planets which exercise the greatest influence are Jupiter and Venus. The planetary agency is directly recognized in the origination of spots on the parts of the sun's surface brought by the rotation into favorable positions, and in the subsequent changes experienced by the spots while subject to the direct action of the planet. It is also shown by the dependence of the epochs of the maximum and minimum of spots upon the positions of the planets, especially of Jupiter and Venus.

"Effects of so marked a character, exerted by the planets upon the photosphere of the sun, cannot reasonably be attributed to their natural attractive action, and must apparently result from a repulsive or impulsive action exerted upon the photospheric matter.

"Some spots have been observed to have a motion of rotation around their centres; but according to Dawes, who has been a diligent observer of solar phenomena for many years, this is a phenomenon of exceedingly rare occurrence in the case of well-developed spots.

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* The citations above are from the fourth edition of Norton's "Treatise of Astronomy." 1878. Pp. 168, 167, 166, 171 and 172.

"The following is a brief outline of a theory of the development of the sun's spots, based upon the principle of planetary action above stated:

"1. The matter of the sun's photosphere, and for a certain distance beyond the luminous surface of the photosphere, is either wholly or in part in a magnetized state, and arranged in columns, or lines of magnetic polarization, like the auroral matter in the upper atmosphere of the earth.

"2. A repulsive or impulsive action exerted by the planets upon the molecules of these columns tends to disturb their electric and magnetic equilibrium, and induce electric discharges along certain of the upper columns, by which they are widely dispersed and the mechanical equilibrium of the portions below disturbed. In this way a vast column of expanding and ascending matter is originated in the photosphere, which in the process becomes more or less dissipated, and may reveal the body of the sun to view.

"3. The matter dispersed, from a loss of magnetic intensity, or by the electric discharges, and certain portions of the vaporous matter of the column, as they rise above the photosphere, are brought into that subtle or nebulous condition observed in the matter of comets, in which it becomes subject to an effective repulsion from the sun, and so is expelled indefinitely into space. Other portions may become condensed above the photosphere, and subside into it.

"4. The planets may be conceived to operate in two ways, to initiate the process of dispersion of the tops of the photospheric columns, and so develop spots on the sun; viz., by originating in the upper photosphere electric currents radiating in all directions from the region exposed to most direct action, or by developing electro-magnetic currents running in a direction opposite to that of the rotation. Such radial electric currents would be attended with an exaltation of the statical electric condition of the region exposed to planetary action; and such magnetic currents would tend to demagnetize, or magnetize, the upper photospheric columns, according as the upper or lower currents prevail.

"It appears, from the results of observation, that the planets operate unequally in different parts of the ecliptic, and in different relative positions; and their effects are apparently modified, in certain positions, by the electro-magnetic currents developed in the sun's photosphere by the motion of the solar system through space.

"5. The spots are more likely to occur in low than in high latitudes, because the induced magnetism of the photospheric columns has a lower intensity in proportion as the magnetic latitude is less; and spots do not make their appearance on the equator, nor in its immediate vicinity, because the columns of magnetic matter are there parallel to the surface of the sun.

"6. In the supposed electric discharges along the magnetic columns, with the attendant accumulation of luminous matter in certain localities above the ordinary surface of the photosphere, we have at the same time an adequate explanation of the *faculæ* [bright specks on the sun's surface, thought to be elevations of luminous matter above the surrounding level], and of the *rose-colored protuberances* at a still higher level.

"When, in special localities, the discharge has attained to a sufficient intensity, or continued for a sufficient length of time, openings are made through the whole depth of the photosphere, and spots are seen in the region where the faculæ were before observed.

"It may be added, in this connection, that the supposition of the distribution of the photospheric matter in separate columnar masses, accords with the granulated appearance presented by the sun's disc.

"7. The photospheric matter dispersed by reason of the varying action of the planets, sufficiently to become subject to a repulsive action from the sun as it flows away into space, forms the *corona*, with its accompanying radiations and streamers, visible in total eclipses.

"8. A portion of the attenuated matter thus expelled to an indefinite distance from the sun, is received into the upper atmosphere of the earth, and, by developing electric currents there, becomes one of the operating causes of the disturbances of the magnetic needle on the earth's surface; which are observed to increase and decrease, *pari passu* with the sun's spots. The impulses attendant upon the electric discharges occurring in the sun's photosphere, and propagated indefinitely into space, constitute another cause of magnetic disturbance upon the earth.

"The escaping solar matter received into the earth's upper atmosphere supplies the matter of terrestrial auroras, which also have the same periods as the sun's spots. (For a more complete exposition of the author's theoretical views, see American Journal of Science, Vol. XLI., Nos. 121 and 122. See also Note in Appendix.)" *

Omitting a table there given, the Note in the Appendix, referred to above, is as follows:

"The fact stated in the text that the penumbra [the partial shadow] of the solar spot does not begin to be formed until the spot, which at first has an umbral blackness [the blackness of a perfect shadow], has attained a measurable size, is cited by astronomical writers as a circumstance strongly favoring the hypothesis of the origination of the spot in a disturbance from below. But this fact may be reconciled with the opposite hypothesis advocated in the text, if we reflect that the penumbral lies at a considerable depth below the luminous envelope, and that the process of discharge and ascent of a column of photospheric matter, which results in disclosing to view a portion of the penumbral envelope, should *occupy a certain interval of time in passing down to it.* During this interval this envelope may have an umbral blackness, and it may owe its subsequent visibility, as distinct from the umbra, entirely to the fact that it acquires a luminosity in consequence of the electric discharges that attend the process of spot evolution, which has penetrated to its depth in the atmosphere of the sun. This view is supported by the fact that it furnishes a simple explanation of the decrease in the brightness of the penumbra from the umbra to its outer margin. We have only to observe that the process of expulsion and ascent of vaporous matter, which begins at a certain point of the photosphere, at the same time that it proceeds downward spreads laterally, and that when it has penetrated to the depth of the penumbral envelope at the point below that where it originated, an opening of a certain size will have been formed in the luminous envelope, and except below the central portions of this opening the lower envelope will still be in a comparatively quiescent condition, and retain its natural depth of shade. Subsequently the same process of evolution is repeated at this envelope; an opening is made in it that has the umbral depth of shade, and this is surrounded by a region of luminous activity, which is the penumbra of the spot, and is fringed by a dark border consisting of the part which the descending action has not yet reached. In the case of the larger spots and of long continuance, the same process penetrates to the third envelope, and the former umbra shows, in its turn, a black central nucleus, surrounded by a fringe of a shade perceptibly less dark.

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* *Ibid.*, pp. 174–5.

"Upon the present hypothesis with regard to the mode of development of the spots, the principal varieties, consisting of a spot without a penumbra, a spot without an umbra, a spot without the central black nucleus at the centre of the umbra, and a spot with this nucleus, are but the varieties which present themselves according as the process of discharge, beginning at the surface of the photosphere, penetrates only through the first envelope, or through the first and as far as the second, or through the first and second, or through the first, second and third. Upon the old hypothesis, it is necessary, in order to explain these diverse phenomena, to assume that there are three possible centres of explosive action, posited below the successive envelopes.

"So long as the active evolution continues at the lower envelopes, the ascending vaporous column, expanding as it rises, should check any eventual tendency of the opening in the luminous envelope to close. When the activity subsides at the penumbral stratum, and the opening in it begins to close, this should be followed by a similar collapse in the regions above it; and so the contraction of a spot should generally begin in accordance with observation at the umbra, and be followed by the encroachment of the luminous margin upon the penumbra. But it is conceivable, also, that the closing up of a spot may result from a condensation into luminous clouds of portions of the expanded matter ascending within the region of the spot; and that the luminous veil which is often seen to form over a spot, and the bridges of light which suddenly span the umbra, are the first indications of the beginning of such condensations.

"To give a more complete exposition of the author's theory of the development of solar spots, the following general conclusions are added to those given in the text.

"1. The spots are, for the most part, due to diminutions occurring in the magnetic intensity that obtains in the photosphere of the sun.

"2. Each planet operates on the photosphere by repulsive impulses, and develops electro-magnetic currents circulating in a direction opposite to that of the rotation. The effective currents thus originating are differential, and result from the fact that on the left or east side of the line from the planet to the sun's centre the motion of the surface is in a direction opposite to that in which the impulses are propagated, and on the other side in the same direction.

"3. The general tendency of such new currents should be to increase the magnetic intensity at the surface of the photosphere; but it is possible that in peculiar conditions of the photospheric matter, as to density and other qualities, the superficial currents developed by planetary action may prevail over those set in motion below the surface, and the opposite magnetic effect be produced.

"4. The motion of the sun through space also develops similar magnetic currents, which should have a similar effect. These currents may be considered as originating on that side of the sun where the absolute motion of a point of its surface is the most rapid.

"5. If the sun were stationary the motion of revolution of a single planet would have but little direct effect to change its magnetic action on the sun as a whole, except so far as this may vary by reason of the varying distance of the planet. But in point of fact the effective action of a planet will change with its distance in longitude from the point towards which the sun is moving in space. It will be at its maximum when the planet is in heliocentric conjunction with this point, and at a minimum when it is in opposition to it. In the former case its heliocentric longitude will be 253 degrees, and in the latter 73 degrees.

"6. The joint magnetic action of two planets varies with their relative position; it has its maximum value when the planets are in conjunction, and its minimum when they are in opposition.

"7. The epochs of conjunction of one planet with another, or of a planet with the point towards which the sun is moving, are in general the epochs of minimum of spots, since the magnetic intensity at the surface of the photosphere is on the increase before every such epoch. The approximate coincidence of planetary conjunctions with special epochs of minimum of spots is a recognized fact in the case of Jupiter and the earth, and Venus and the earth. On the other hand, the opposition of two planets tends to determine a maximum of spots.

"8. Jupiter and Venus are the most influential planets. The period of the spots is determined mainly by the motion of revolution of Jupiter, but appears to be modified by the varying planetary configurations, and also by changes occurring in the physical condition of the sun's photosphere. The varying action of Jupiter, in the course of a revolution, has been attributed to its variations of distance from the sun, but it seems improbable that effects so marked should result from so light a cause. The mean period of the spots is, according to Wolf, nearly one year, and, according to Schwabe, nearly two years less than Jupiter's period of revolution. This difference cannot be explained by any mere recurrence of planetary configurations. In fact, epochs of maximum and minimum of spots have occurred under every variety of configurations; and also when Jupiter has had every variety of position in its orbit. The following Table shows the mean positions of Jupiter and Saturn at various such epochs, from 1750 to 1860; together with the relative numbers showing, according to Wolf, the spot-condition of the sun. [The Table is here omitted.]

"It will be seen that since 1761 the maxima have occurred when Jupiter was in the second or third quadrant of longitude, and that since 1755 the minima have occurred when he was in the other two quadrants. But previous to those dates the condition of things was reversed, and the transition from the one condition to the other was gradual. This fact seems to necessitate the supposition that the physical condition of the sun's photosphere is liable to changes, by reason of which the ordinary effect of the planets is, at intervals, wholly reversed.

"9. The highest maxima of spots have occurred when Jupiter was in the second quadrant of longitude—that is, after he has passed a certain distance beyond the point (long. 73 degrees) where his magnetic action on the sun is most directly opposed to the effect of the sun's motion through space, and advanced towards the aphelion of the orbit, where the direct magnetizing tendency of the planet is the least.

"It should here be remarked that the author has undertaken, in other publications, to show that the earth derives its magnetic condition from the collision of the molecules of its revolving and rotating mass with the ether of space, and that the sun and the planets should each be in a magnetized condition from a similar cause; also that in the new terrestrial magnetic currents being continually developed by the earth's motions of revolution and rotation combined, in connection with those generated in the photosphere (upper atmosphere) of the earth by ethereal impulses, and streams of nebulous matter proceeding from the sun, we have the principal operative causes of the disturbances experienced by the magnetic needle on the earth's surface." *

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* *Ibid.*, pp. 434-6.

The hypothesis of a preponderating influence of Jupiter upon the solar sun-spot cycle is of course not essential to such a theory. The present state of uncertainty on this point is well illustrated by the following account of recent astronomical opinion:

"The idea that solar maculation depends in some way upon the position of the planets occurred to Galileo in 1612. It has been industriously sifted by a whole bevy of modern solar physicists. Wolf, in 1859, found reason to believe that the eleven-year curve is determined by the action of Jupiter, modified by that of Saturn, and diversified by influences proceeding from the earth and Venus. Its tempting approach to agreement with Jupiter's period of revolution round the sun, indeed, irresistibly suggested a causal connection; yet it does not seem that the most skilful 'coaxing' of figures can bring about a fundamental harmony. Carrington pointed out in 1863 that, while during *eight successive periods*, from 1770 downwards, there were approximate coincidences between Jupiter's aphelion passages and sun-spot maxima, the relation had been almost exactly reversed in the two periods preceding that date; and the latest conclusion of M. Wolf himself is that the Jovian origin must be abandoned. M. Duponchel, of Paris, was nevertheless not wholly unsuccessful in accommodating discrepancies with the help of perturbations by the large exterior planets; since his prediction of an abnormal lengthening of the maximum of 1883-4, through certain peculiarities in the positions of Uranus and Neptune about the time it fell due, was partially verified by the event. The previous maximum having occurred in June, 1870, the next phase of agitation should, if punctual, have culminated about August, 1881; whereas, after an abortive effort at completion in April, 1882, the final outburst was postponed to November, 1883. The interval was thus 13.3 instead of 11.1 years; and it is noticeable that the delay affected chiefly the southern hemisphere. Alternations of activity in the solar hemispheres were indeed a marked feature of the maximum of 1883-4, which, in M. Faye's view, derived thence its indecisive character, while sharp strong crises arise with the simultaneous advance of agitation north and south of the solar equator. The curve of [terrestrial] magnetic disturbance, it should be added, followed with its usual strict fidelity the anomalous fluctuations of the sun-spot curve." *

It is well known that the supposition of a relation between the orbital period of Jupiter and the cycle of sun-spots has been strengthened by an alleged additional coincidence between the periodical recurrence of certain markings on Jupiter and of spots on the sun. On this last point the writer just quoted says:

"In 1870 Mr. Ranyard, acting upon an earlier suggestion of Dr. Huggins, collected records of unusual appearances on the disc of Jupiter, with a view to investigate the question of their recurrence at regular intervals. He concluded that the development of the deeper tinges of color, and of the equatorial 'port-hole' markings girdling the globe in regular alternations of bright and dusky, agreed, so far as could be ascertained, with epochs of sun-spot maximum. The further inquiries of Dr. Lohse, at Bothkamp, in 1873, went to strengthen the coincidence, which had been anticipated *à priori* by Zöllner in 1871. Yet subsequent experience has rather added to than removed doubts as to the validity of that first conclusion. It may, indeed, be taken for granted that what Hahn terms the universal pulse of the solar system affects the vicissitudes of Jupiter; but the law of those vicissitudes is far from being so obviously subordinate to the rythmical flow of central disturbance as are certain terrestrial phenomena. The great planet being in fact himself a 'semi-sun,' may be regarded as an originator, no less than a recipient of agitating influences, the combined effects of which may well appear insubordinate to any obvious law." *

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* Clerke's "History of Astronomy." Third edition, 1893, pp. 202-3.

The reasonableness of the view that not merely Jupiter, but every satellite of the sun, must respond in a delicate way to each phase of electro-magnetic solar disturbance, is at once apparent when we reflect upon the remarkable response of the earth to the slightest solar pulsations. This response is revealed by the perturbations of a freely-suspended magnetic needle, in respect to the three magnetic elements of intensity of magnetic force, declination and dip. The earth is a great magnet, with its axis of polarity approximately forming right angles with the plane of the earth's geographical equator. This is precisely what we should expect, provided that the magnetism of the earth is a consequence of equatorial electrical currents around the earth, induced by the apparent daily revolutions of sun and moon. In the northern hemisphere there are two poles, or foci, of magnetic force, the more stable and energetic one being situated in northern North America, and the weaker and less stationary one in northern Siberia. In the southern hemisphere the two magnetic foci are closer together.

It is a well-known fact that unlike magnetic poles attract, and like magnetic poles repel one another. It is also an experimental fact that the attractive energy of any magnet is least at its centre, and increases as either pole is approached. The magnetic needle obeys both these laws. Its north pole is repelled by the magnetic north-pole of the earth, and attracted by the earth's magnetic south-pole, while its south-pole is affected in the reverse way. When the needle is delicately poised, therefore, and free to obey these influences, it arranges itself in a north and south direction—each pole thus approaching that of the earth which attracts it. At the magnetic equator, which is approximately the geographical equator, it is plain that the attractive energy of the earth's north magnetic pole practically equalizes that of the south magnetic pole, and the needle is poised in comparative equilibrium. From this point the magnetic force increases as we approach either pole.

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* *Ibid.*, p. 362.

If we carry the magnetic needle north, the influence of the north magnetic pole of the earth preponderates over the influence of the terrestrial south magnetic pole, and the needle obeys the stronger force, the result being that the needle "dips," the attracted end pointing downward directly toward the north magnetic pole, while the repelled end points upward, away from the north magnetic pole, the diminished force of the earth's south magnetic pole being unable to prevent this. As we proceed north the dip of the needle continues until, directly over the north magnetic pole, the needle is vertical to the earth's surface, its attracted pole pointing downward and its repelled pole pointing toward the zenith of the heavens. In the southern hemisphere the preponderating influence of the earth's south magnetic pole produces a like dip of the opposite pole of the needle. A moment's reflection will show that this dip of the needle, increasing north and south of the equator, is one of the best indications of the spherical form of the earth.

The intensity of magnetic force increases from equator to poles, much as does the dip of the needle, the degree of intensity being determined by counting and measuring the vibrations. The other magnetic element, declination, depends primarily upon longitude. If the magnetic and geographical poles of the earth were coincident, it is plain that a needle pointing toward the north magnetic pole would always point due north. But, since this is not the case, it follows that a needle which points toward the north magnetic pole will, from nearly all stations in the northern hemisphere, point more or less west or east of the geographical north pole, the degree either way being determined by the position of the needle with respect to the magnetic and geographical poles. In the southern hemisphere a like deviation from the true south is characteristic of most stations. This variation of the magnetic needle from the true meridian of a given place is called its declination east or west for that place. Two foci of magnetic force in each hemisphere complicate this result, but do not alter the principle.

Were the electro-magnetic state of the earth an inflexibly stable condition, it is obvious that at a given geographical station on the earth the three magnetic elements, intensity, dip and declination, would never vary. But, in point of fact, there are constant variations of the elements characteristic of a station, and these are found to be classifiable as phenomena of periodic recurrence. We will briefly notice the chief cycles, beginning with the shortest:

1. We have, first, a daily cycle of solar and a daily cycle of lunar magnetic disturbances. Under the influence of the sun the needle does not point steadily toward the magnetic pole of the earth, but daily swings east or west of this pole, the declination to one side reaching its maximum about four hours before noon, and that to the other side about two hours after the sun has crossed the meridian. There is a similar oscillation when the sun is near the meridian on the opposite side of the earth, the maximum on one side being attained four hours before, and on the other side two hours after, mid-

night. Each lunar day, of twenty-four hours and fifty-four minutes, similarly witnesses a less powerful but very distinct double declination, one reaching its extremes before and after the lunar noon, and the other before and after the lunar midnight; just as in the case of the sun. In respect to dip and magnetic intensity, the solar and lunar daily cycles of disturbances are very similar.

2. There is also a twenty-six-day cycle of magnetic disturbances, the daily oscillations of the needle observing a series of modifications, the progress of which recurs at such intervals. Mr. M. A. Veeder, of Lyons, New York, has called attention to the fact that the auroral displays also reveal a twenty-six-day periodicity. This cycle no doubt depends in some way upon the axial rotation of the sun, different portions of whose photosphere rotate in different periods ranging from twenty-four to twenty-seven and a half days. The very plausible theory of the late Prof. Balfour Stewart was that a solar meridian of peculiar magnetic power, upon the rotation of which the twenty-six-cycle depends, may have a proper motion of its own which is subject to a margin of modification under planetary influences. Broun and Hornstein were among the first to note the twenty-six-day cycle in connection with the magnetic needle.

3. The diurnal oscillations of the needle, due to lunar influence, are likewise subject to modifications coincident with the lunar month of twenty-nine and one-half days, the diurnal variations being greater for perigee, when the moon is nearest the earth, than for apogee, when it reaches the most distant point in its orbit. This was established by Broun and Sabine. Again, Capello, Stewart and C. Chambers have shown that the declination of the needle due to lunar influence reaches a maximum at the time of each new and full moon, or when the moon is in conjunction with and in opposition to the sun.

4. There is a marked cycle of magnetic variations of annual recurrence. At any given hour the motion of the magnetic needle in the northern hemisphere is always in the direction opposite to that of its motion in the southern hemisphere. From the vernal to the autumnal equinox one type of oscillations prevails in the northern hemisphere and an opposite type in the southern hemisphere, while from the autumnal to the vernal equinox this scheme is reversed, the southern type prevailing in the northern hemisphere and the northern type prevailing in the southern hemisphere. The same reversal of magnetic seasons in the two hemispheres is likewise observed in connection with the northern and southern types of lunar oscillations. The change of magnetic seasons is closely analogous to that of the meteorological seasons. The facts under this head were established by the observations of Canton, Macdonald, Duperrey, Sabine and Broun.

5. A further cycle coincident with the solar year was announced by Canton in 1759. Observations in the north temperate zone show that the range of declination of the needle reaches a maximum about the time of the sum-

mer solstice, and a minimum about the time of the winter solstice, with additional maxima about the times of both vernal and autumnal equinoxes. Again, the magnetic intensity and dip of the needle—elements which are closely related—are found to be greatest at the times of the solstices, and least at the times of the equinoxes. Assuming that the sun acts indirectly upon the magnetic system of the earth, and in close connection with the convection currents of the earth's atmoshere, Professor Balfour Stewart reasoned that "solar action would act most strongly on the earth's magnetic poles at the solstices, and that in the June solstice the pole or poles in the northern hemisphere, and in the December solstice those in the southern hemisphere, would be most affected," while, "if the solar magnetic influence is connected with the convection currents of the earth, we can readily imagine that the influence in the northern hemisphere, where there is much land, should exceed that in the southern hemisphere, where there is much water." Thus this theory requires that "(1) the earth's induction system should be stronger at the solstices than at the equinoxes, and (2) [that] it should be more especially strong at the June solstice, when the sun acts in the northern hemisphere,"—theoretical deductions which agree with observations.

6. Solar influence, as a cause of the disturbance of magnetic equilibrium revealed in the fluctuations of the magnetic needle, also varies in amount from year to year during a cycle approximately of 11.11 years, the period of which, however, ranges at times from a little less than seven and a half years to sixteen and a half years. During each cycle the sun's surface exhibits a maximum of spots and a minimum of spots, the years intervening between the two being characterized by a gradual decrease or increase in the number of spots according as the progress is from a maximum to a minimum or from a minimum to a maximum. During this cycle the corona of the sun likewise varies between two distinct types, one of which is characteristic of the period of numerous spots and the other characteristic of the period of comparatively few spots, the natural inference being that the character, or energy, of solar radiation varies accordingly. When the cycle is shorter than the normal, the contrast between the maximum and minimum of spots is more extreme than usual, whereas it is less extreme than usual when the period of the cycle is longer than the normal. This suggests the hypothesis that in all cycles the electro-magnetic stress which is induced and relieved is approximately the same in amount, but that influences which are yet to be determined induce this condition (which then relieves itself) in shorter periods at one time than at another.

In 1852, Sabine, Wolf and Gautier independently discovered that the declination of the magnetic needle is dependent upon the sun-spot cycle, the range of declination becoming progressively larger with the approach to a maximum of spots, and diminishing in perfect accord wlth the progress toward each minimum. Balfour Stewart showed that the effect on the needle always manifests itself subsequent to the appearance of disturbance on the sun, demonstrating that the relation of the two is undoubtedly that of cause and effect. In 1879, Ellis announced that the diurnal range of magnetic intensity increases and decreases with the rise and fall of sun-spot activity precisely as does the range in declination, showing at the same time that the terrestrial effect *follows* the solar cause. The investigations of Professor Loomis, published in 1870 and 1873, demonstrate a periodicity in the frequency and intensity of displays of the aurora borealis coincident with the eleven-year solar cycle, the maximum of auroral activity, however, occurring a little later than the maximum of sun-spots and of disturbances of the magnetic needle, although the minimum of auroral activity more perfectly coincides with the minimum of sun-spots. Since electricity passed through rarefied air perfectly reproduces, on a small scale, the auroral display of tremulous, luminous streamers, we can scarcely doubt that the latter are caused by the passage of electricity through the upper air-layers. It has likewise been determined that the frequency of occurrence of so-called electrical storms and electrical earth-currents waxes and wanes with the increase and decrease of sun-spots.

7. By independent investigators a solar cycle of fifty-five and a half years, embracing five eleven-year cycles, has been announced, while by Herman Fritz it was pointed out that this longer cycle is as characteristic of the aurora borealis as of the sun-spots. There is little doubt that the fluctuations of the magnetic needle would also disclose a periodicity coincident with this longer cycle were there an accurate record of the magnetic elements for a sufficient term of years to test the question.

8. Finally, Herman Fritz has also announced a still longer cycle of 222 years, embracing four fifty-five-year cycles, during the course of which these cycles are found to recur in a typical order which is repeated during the next period of 222 years, while this is as true of the aurora borealis as it is of the sun-spots.

Since the electro-magnetic condition of the earth responds in so delicate a manner to the influence, not alone of the sun, but of a small and cool body like the moon, there is a presumption that all the members of the solar system together exhibit an intricate scheme of electro-magnetic actions and reactions, the magnitudes of which are in each case proportional to the physical constitution, physical condition, temperature and surfaces of the bodies involved, and inversely as the square of the distance berween them. We suspect that, were the elements of all the planets carefully correlated, together with those of periodic comets and meteors, the various cycles of magnetic disturbance would be found to be coincident with the recurrence of like, or equivalent, planetary configurations.

Professor Norton's hypothesis that earth, sun and planets are magnetized in virtue of their orbital and axial motions through the ether of space is very plausible, and has found numerous champions among scientists. In the case of the earth, this view was recently referred to in favorable terms by Professor Henry A. Rowland. *

Upon this hypothesis. if we accept the Copernican theory, we would attribute the permanent magnetism of the earth to its motions in space, and the periodic fluctuations in its amount to the effect of radiant energy, received principally from sun and moon. We thus assume, of course, that electrical phenomena are the effects upon matter caused by stresses of ether analogous to if not identical with those vibrations of ether whose effects upon matter we recognize as phenomena of heat and light, the stress being originally imparted to the ether by vibrating matter, and propagated through it in the form of waves.

If we assume the truth of the Tychonic theory, the permanent magnetism of the earth, as well as the fluctuations in its intensity, would be entirely referable to celestial radiation. But powerful effects of this kind are precisely what we should anticipate on this basis, in view of the exceedingly swift motions through space of sun, moon, planets, stars and comets, in describing orbits about the earth in approximately twenty-four hours. If it be in any case allowable to conceive of electrical excitement as an effect of translation through space, the velocities required by Tychonic theory should develop electrical potential sufficient to produce, we believe, all the phenomena of attraction now referred to gravitation, as well as all the phenomena of attraction and repulsion already conceded to be of an electro-magnetic nature.

The universal sway of gravitation is not questioned in Professor Norton's theory of solar electrical disturbances. His hypothesis is merely of an auxilliary character, designed to account for phenomena which can in no wise be referred to gravitation—phenomena due, in fact, to an energy diametrically opposed to gravitation, being repulsive instead of attractive, and which is much more powerful than gravitation, provided that universal gravitation actually prevails, since in that case it is plain that no repulsive energy can become recognizable as such unless it is powerful enough entirely to overcome the force of gravitation and solicit matter in a direction opposed to that which it should take in obedience to the law of gravitation. We may conveniently adopt Professor Norton's theory as our own, therefore, in explaining all forms of solar repulsion which are not of a strictly thermal nature, although it must be plain to all that our modification of his theory does not require anything like the same degree of repulsive energy in order to account for the phenomena. For in conceding an attractive force of universal and constant operation, Professor Norton places himself under the necessity of supposing a repulsive force which must always overcome gravity before it can produce repulsive phenomena.

But we doubt the existence of an occult force of universal gravitation,

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* "American Journal of Science." December, 1899.

believing that the attractive energy of the solar system is as truly electro-magnetic in its nature as is its repulsive energy. From what we know of electro-magnetic attraction and repulsion at the earth's surface, we do not suppose that these opposite energies are ever in operation between two particles at the same moment, but that they succeed one another, the energy of attraction ceasing before the energy of repulsion is developed. And this is what we should expect in the case of matter in the solar system, provided that the nature of celestial attraction is electro-magnetic and not gravitational. Hence, accepting Professor Norton's theory, thus qualified, as sufficiently accounting for the phenomena of solar repulsion to suit our present purpose, it remains for us to show that the energy of attraction which plays so important a part in the solar system can also be rationally conceived of as electro-magnetic in its nature, rather than gravitational.

A. It has been experimentally determined that electrical and magnetic attractions and repulsions vary in intensity inversely as the square of the distance between the bodies concerned. This is in perfect agreement with the law of the attractions in evidence in the solar system.

B. It has been assumed that the celestial attractions are directly proportional to the masses involved, whereas it is certain that electro-magnetic attractions are not, but are rather proportional to the physical constitution of the bodies of matter involved, their physical condition, their temperature, and the nature and extent of the surfaces upon which the electrical charges accumulate. Here we face a contradiction which would be fatal to our theory, provided that the part of Newton's law which states that gravitation is proportional to the masses were anything more than a barren assumption, in favor of which not a grain of trustworthy experimental evidence has been secured. The truth is that all the present calculations of masses, including those of the earth, the moon, the planets and asteroids, the planetary satellites, the stars and the comets, are simply obtained by first assuming that attraction is proportional to the masses, and then calculating on this basis the masses which will approximately agree with the observed configurations and motions. Thus in his presidential address before the Physical Society of America, in October, 1899, Professor Henry A. Rowland, of Johns Hopkins University, justly observed that "that portion of the law which says that gravitational attraction is proportional to the quantity of matter, which is the same as saying that the attraction of one body by another is not affected by the presence of a third—the feeble proof that we give by weighing bodies in a balance in different positions with respect to each other cannot be accepted on a larger scale. When we can tear the sun into two portions and prove that either of the two halves attracts half as much as the whole, then we shall have a proof worth mentioning." Again he says: "We measure the lunar distance and the size of the earth and compare the force at that distance with the force of gravitation on the earth's surface. But to do this we must compare the matter in the earth with that in the sun. This we can only do by *as-*

suming the law to be proved. Again, in descending from the earth's gravitation to that of two small bodies, as in the Cavendish experiment, we *assume* the law to hold and deduce the mass of the earth in terms of our unit of mass. Hence, when we say that the mass of the earth is five and one-half times that of an equal volume of water, we *assume* the law of gravitation to be that of Newton. Thus a proof of the law from planetary down to terrestrial distances is physically impossible." By consulting a good work on astronomy or physics any reader can satisfy himself that the calculated masses of the earth and sun are obtained only by assuming as true that for which we have no evidence—that the attraction of matter is proportional to the masses, while all other masses in the solar system are deduced on the basis of the mass thus assigned to the sun. Therefore the force of Professor Rowland's criticism cannot be avoided. Yet this is merely to say that the hypothesis that attraction is proportional to the masses has never been experimentally demonstrated. On the other hand, are there any other facts which appear to be inconsistent with it? In the first place there is the fact that the opposite kind of energy, electrical repulsion, most certainly is *not* proportional to the masses involved; for if it were, and universal gravitation constantly acts, repulsive phenomena would be impossible, as we have shown. For since both these forces vary in intensity inversely as the square of the distance through which they act, if the intensity in each case were also proportional to the masses involved, when both forces were in operation at the same moment between any two particles they would exactly neutralize one another, and the two particles would remain stationary. But repulsive phenomena are facts of nature, so that the energy which causes them overcomes gravitation, if gravitation is a fact. Hence, since electrical repulsive energy agrees with gravitation in obeying the law of the inverse square, it cannot at the same time agree with it in obeying that of proportion to the masses. In the second place, the mutual action observed between celestial bodies is such, in some cases at least, that it is impossible for it to be gravitational, or proportional to the masses involved, provided that the ordinary attractions between the celestial bodies are proportional to the masses computed for these bodies. Such mutual action has been observed in the case of the two sections of Biela's comet, reference to which will be made in Part VII., immediately following this chapter.

C. It is not necessary for us to suppose that the attraction which the earth exerts is precisely like that which is in operation between the sun and planets. Tychonic theory places the earth in the centre of the evolutions of the celestial orbs, and the transformation of the earth into a huge magnet we may attribute to this cause. Hence gravity at the earth's surface we may assume to be the measure of the intensity of the permanent magnetism of the earth—an influence which is sufficient to hold the moon in her elliptical orbit, and extends indefinitely into space, diminishing as the square of the distance increases. But sun, moon, planets, stars and comets, which rapidly move through space, we would not regard as permanent magnets; but rather as masses of electrified matter.

D. Assigning to the planets the same original velocities assigned to them by Newtonian-Copernican theory, and recognizing that they move in elliptical orbits, in approximate conformity to Kepler's laws, we conceive of them as constantly solicited towards the sun by an attractive force due to the fact that both sun and planets are statically charged with electricity, the charges of the sun being of one sign, and those of the planets being of another. Since the attraction is not sufficient to cause the planets to leave their present nearly circular orbits, they never approach the sun close enough to enable the stress in any case to be fully relieved by electrical discharges across the non-conducting ether. Therefore the electrical states of sun and planet continue to remain of opposite signs, the attraction never giving place to repulsion.

E. The satellites of the planets are statically charged with electricity of the same sign as that of the sun, or unlike that of the planets, so that they are constantly solicited towards the planets, just as the latter are solicited towards the sun.

F. In the case of a comet we have a mass of matter which is a good conductor of electricity. It is a well-known fact that an electric charge is induced in a conductor when the latter is brought into the electrostatic field of an electrified body, and that this charge is of opposite signs at the two extremities of the conductor. Thus we assume that the comet is solicited towards the sun precisely as is the planet, but as it approaches the sun electrostatic induction takes place. According to theory, the end of the comet approaching the sun should be charged with electricity of opposite sign to that of the sun, and thus should be attracted towards him, while the other extremity of the cometary matter should be charged with electricity of the same sign as that of the sun, and should be repelled. Now this is exactly what we find in the case of comets, the head or nucleus being solicited towards the sun at the same time that repelled cometary matter streams away in the opposite direction.

G. Solar radiation, and the much less energetic radiation of the other celestial bodies, would be accounted for by the difference of electrical potential perpetually existing between sun and planets, and the planets and their satellites, on account of their unlike electrostatic conditions, while yet through the non-conducting ether these radiant discharges would never be sufficient to relieve the existing stresses and so derange the system.

PART VII.

THE ELECTRICAL THEORY OF COMETS.

The main facts respecting comets, consistency with which must be maintained in any rational theory attempting to account for the phenomena they present, may be summarized as follows:

1. Spectroscopic analysis has shown them to be largely self-luminous, and largely formed of incandescent gases. This was first demonstrated by Donati's analysis of the light emitted by Tempel's comet in 1864. In 1868 Dr. Huggins identified the spectrum of Winnecke's comet with that of a hydro-carbon compound, acetylene or olefiant-gas, when rendered luminous in a vacuum-tube by electricity. This has been found characteristic of nearly all comets since that time. The chemical formula of acetylene is C_2H_2, and it is one of an analogous group of hydrocarbons styled the acetylene series, all of which exhibit practically the same spectrum. In the cases of some comets the acetylene spectrum was slightly modified, and since Vogel and Hasselberg have obtained this modification by mixing carbonic oxid (CO) with acetylene, it is supposed that this mixture is a constituent of some comets. Both of these substances are lighter than air. Bright lines characteristic of sodium and iron have also been identified in the spectra of a few comets. The metals, iron, nickel, cobalt, tin, copper and chromium, characteristic of metallic meteorites, with phosphorus, carbon and a dozen other elements, may be considered as frequent constituents of comets, on the probable hypothesis that meteorites are condensed fragments of comets.

2. The luminosity of comets is undoubtedly an electrical phenomenon, for whether acetylene be used, or a mixture of carbonic oxid and acetylene, a spectrum comparable with that of most comets is only obtained by passing disruptive electrical discharges through the gases.

3. In the case of Well's comet of 1882, the spectrum of the hydrocarbons dwindled to extinction as it approached the sun, giving place to the spectrum of sodium. Wiedemann had similarly found that the spectra of gases in vacuum tubes are extinguished when metals are introduced and rendered volatile, the metallic vapors thenceforth transmitting the electrical discharges. This is probably what occurred in the case of this comet, electricity being the cause of the phenomenon; since, as remarked by Hasselberg, while the sun's heat might have raised the sodium to incandescence, it would not have effaced the glow of the hydrocarbons. In the case of the great comet of September, 1882, the like phenomenon in reverse order was observed: the spectrum of sodium dwindled as the comet receded from the sun, giving place to the spectrum of acetylene.

4. The comet discovered by Pons, in 1812, upon its return in 1883-4, was subject to a cycle of changes, all of which were executed in a period of

four hours on one occasion, January 1, 1884. From the appearance of a faint nebulæ, it changed to that of a bright star of the eighth magitude; then became eight times as bright, like a star of the second magnitude, with a slight double tail; after which it faded until it had the appearance of a nebulous disk, subsequently resuming its original dimness. Such an evolution in so brief a period, taken together with the fact of its repetition in different periods of time, is scarcely reconcilable with any except an electrical theory of cometary illumination. Yet to admit this is to admit the force of the argument that the analogous phenomena observed in the cases of many variable stars are only explicable on the same hypothesis.

5. Comets contract in bulk when approaching the sun and expand when receding from it. In some cases this phenomenon is of a most astounding nature. Thus, in 1828, during two months of the period of its approach to the sun, Encke's comet dwindled until its original volume was one-eleven-thousandth of that possessed when nearer the sun, while there was a corresponding expansion when it retreated from the sun. Upon the return of the same comet, in 1838, the shrinkage in approaching the sun, and expansion in receding from him, was such that the volume of the comet when distant was 800.000 times as great as when near the sun! If the influence of the sun upon the comet were thermal in its nature, the comet should rather expand when approaching and contract when receding from the solar vicinity.

6. When it first comes within the range of the telescope, a comet generally shines with a faint light and develops no tail. As it approaches the sun its light becomes brighter and a tail is developed, the extension of the tail being away from the sun, as if composed of matter streaming from the head of the comet under the influence of some repulsive energy exerted by the sun. When perihelion has been reached and the comet recedes from the sun, the tail *precedes* the head, leaving little doubt that the development of the tail is an effect of solar repulsion, or of electrical repulsion acting in part from the comet's head. Both causes are undoubtedly operative, for in some cases, if not generally, a portion of the matter constituting the tail appears to issue from the head of the comet on the side toward the sun, and is then bent back behind the head and streams off as a tail, as if repelled by the sun. Zenker, Faye, Ranyard, and the anonymous author of "The Cosmical Force of Thermal Repulsion" (New York), have attempted to account for the phenomenon of comets' tails as an effect of solar heat; but this view is utterly irreconcilable with the fact stated above, that the cometary matter contracts, instead of expanding, as it approaches the sun, and expands instead of contracting as it recedes.

7. The density of the tails of comets must be very much less even than that of hydrogen gas under terrestrial conditions. For the faintest telescopic stars are distinctly visible when the observer is looking through layers of the cometary matter hundreds of thousands of miles in depth. According to Olbers, the earth passed through the tail of a comet on June 26, 1819. No

effect was observed which could be referred to this fact as its cause. Again, on June 30, 1861, according to various astronomers, the earth was completely immersed in a comet's tail, the only possible effect being a "glare" in the sky during the night of June 30, and a disturbance of the magnetic needle on the following night.

8. Even the brightest comets are visible during but a short section of their orbits, in which they approach the sun. "Telescopic" comets never become bright enough to be visible to the naked eye. Nearly all comets, when first seen, appear as faint patches of nebulous matter. As they approach the sun a bright centre develops, called the nucleus. When the comet is fully developed, the nucleus appears like a star or planet, and is surrounded on all sides by a nebulous mass called the coma or envelope, which diminishes in brightness with its distance from the nucleus. Nucleus and coma together constitute the head of the comet. From these the tail issues, streaming out into space, generally a hollow cone-shaped cylinder of matter, increasing in size and diminishing in density and brightness with the distance from the head. It is evident that the tail is hollow, from the fact that it is always brighter at the edges than in the middle, while only a cylindrical formation will always present more matter to the line of sight at the outer edges.

9. Whatever may be the nature of the solar agency which repels the matter in the tails of comets and raises it to incandescence, its operation is sometimes observable in the formation of a tail extending to a distance more than six times that of the earth from the sun. Newton has recorded that the tail of the great comet of 1680 was at one time 123,000,000 miles in length. At the time when it became visible the tail of the great comet of 1843 was 200,000,000 miles in length, while Boguslawski calculated that its length, on March 21, was 581,000,000 miles.

10. As has been elsewhere shown, the velocity with which matter flashes from the head to the extremity of the tail of a comet is sometimes approximately that of light.

11. Comets approach the sun from all directions, in orbits exhibiting every variety of inclination to the plane of the ecliptic. Many comets are known to be members of the solar system, while it is not certain that any comet which has ever been observed is not a member. Any circle or ellipse forms a curve which returns into itself, while a parabola or hyperbola is a curve which does not. At every distance from an attracting centre there is a certain velocity which insures that the body possessing it will move in a parabola, while any less velocity will make the orbit traveled an ellipse, and any greater velocity will make it a hyperbola. Now the velocities of most comets, taken in connection with their distances from the sun, are such that it is doubtful whether their orbits are elliptical, parabolic or hyperbolic, the probability being in almost every case that the orbit is an extremely elongated ellipse. In a very few cases it was calculated that the velocity slightly exceeded that possible

in an elliptical orbit; but the margin of possible error in these cases is such that we cannot positively assert that any cometary orbit is not elliptical.

12. A large number of comets are known to perform revolutions about the sun in comparatively short periods, ranging from about three to sixteen years. The orbits of about twenty-five of these do not extend as far from the sun as the orbit of the planet Saturn, while all the comets of this class move from west to east like the planets, and in orbits inclined to the plane of the ecliptic not much more than are those of some of the asteroids. These orbits are ellipses much more eccentric than those of planets, but much less elongated than those of other comets.

13. The orbit of Encke's comet is within that of Jupiter, while about twenty-five other cometary orbits extend just beyond that of this planet. Tisserand, Callandreau and Professor Newton, of Yale, with others, advocate the theory that these comets have been "captured" by Jupiter, their original orbits having been modified by his influence. A similar hypothesis is applied to the nine comets whose aphelia, or furthest points from the sun, occur in the vicinity of the orbit of Saturn, to the eight comets which extend about to the orbit of Uranus, and to the five which extend about to the orbit of Neptune.

14. The five comets which extend to the vicinity of Neptune's orbit have the longest periods of any whose periodicity has been established beyond question. One of these, known as Halley's comet, was the first whose return was accurately predicted and the prediction verified. Computing its orbit upon its appearance in 1682, Halley assigned to it a period of between seventy-five and seventy-six years, while he found that its orbit and period, as calculated, rendered probable its identification with the comet observed by Kepler in 1607, by Peter Apian in 1531, and by others in 1456. He accordingly predicted its reappearance in 1757. Clairaut subsequently calculated that it would suffer a retardation of 618 days, caused by the influence of Jupiter and Saturn. On December 30, 1758, a comet appeared, describing an orbit apparently identical with that which Halley had computed, while its perihelion passage occurred within the period predicted by Clairaut. It reappeared in 1835, and will be due again in 1910, provided that an acceleration induced by Jupiter's influence takes place as predicted. Its reappearances have been supposedly traced back in old records to 11 B. C., by the researches of Mr. Hind and Professor Angström. In 1066, and again in 1456, it was particularly bright. Another comet of the Neptune group was discovered by Pons, July 20, 1812, while Encke computed its period at seventy-one years. Its reappearance occurred in the fall of 1883. This is the comet, referred to above, which passed through the remarkable cycles of changes, one of which exhibited all its phases in four hours.

15, The periodical comets of short terms, whose aphelia are situated in the vicinity of Jupiter's orbit, either are "telescopic" comets, or else are but faintly visible to the eye, while they develop very slight tails. This is accounted for on the "capture" hypothesis, by supposing them to have originally described parabolic orbits, or elliptical orbits of great eccentricity, which were changed through the influence of the planets, and especially of Jupiter. Their approach to the sun becoming thus much more frequent, they are supposed to have been more rapidly reduced in bulk than are the comets of longer periods in virtue of being more frequently subjected to the loss of matter through solar repulsion.

The behavior of Biela's comet is cited as a strong argument in favor of this view. After its discovery by Von Biela, in 1826, a period of six and two-thirds years was assigned to it, and it was identified with comets which appeared in 1772 and 1805. Between 1805 and 1826 its brightness so diminished that it ceased to be visible to the naked eye. On November 28, 1845, it put in its periodic appearance as usual, as a faint nebulous cloud; on December 19 assumed the form of a pear, and by December 29 had effected a separation into two bodies of unequal size. In February, 1846, the smaller and fainter fragment increased in brilliancy until it was as bright as the other portion, after which it waned and disappeared. It was calculated that the two comets were about 200,000 miles apart. When they reappeared, in 1852, the two fragments were nearly 1,500,000 miles apart, while first one part and then the other waxed the brighter. Neither of the components has been seen since, although eagerly searched for as their periods of approach to perihelion drew near, while 1872 should have been especially favorable for their observation. Whatever may have been the cause of the phenomenon, we evidently have here the case of the disintegration of a comet.

On the other hand, Encke's comet affords a remarkable example of very frequent returns to perihelion without any apparent results of disintegration. The period of this comet, about three and one-third years, is the shortest known. It has passed its perihelion some thirty-four times since it was first observed, in 1786, or very much oftener than has any other comet which has been observed; while yet there is no evidence of a process of disintegration. We may, perhaps, account for such opposite phenomena as those presented by Biela's and Encke's comets by supposing that disintegration is chiefly due to peculiar electrical conditions, and not merely to a gradual process proportional in every case to the frequency of perihelion passages.

16. Since there is great uncertainty whether the orbits of the comets of long periods are parabolic or elliptical, there is a corresponding margin of doubt in the computations of their orbits. Of several hundred comets of this class, about one-half have an orbital motion in the same direction as that of the planets, while the other half have a retrograde motion like that of Halley's comet. Their very eccentric orbits are also inclined at all angles to the plane of the ecliptic.

17. Sir William Herschel and Laplace assumed that all comets naturally wander through space in open orbits, while those which approach our sun,

by chance, generally speed away again never to return, although a certain number have been forced to move in elliptical orbits by planetary attraction, and thus have become permanent members of the solar system. Many of the very serious objections to this view have been brought together by Miss Clerke, as follows:

"There was a difficulty. No comet has yet been observed to travel in a decided hyperbola. The typical cometary orbit, apart from disturbance, is parabolic; that is to say, it is indistinguishable from an enormously long ellipse. But this circumstance could only be reconciled with the view that the bodies thus moving were casual visitors from outer space by making, as Laplace did, the tacit assumption that the solar system was at rest. His reasoning was indeed thereby completely vitiated, as Gauss pointed out in 1815; and his objections were reiterated by Schiaparelli, who demonstrated in 1871 that a large preponderance of well-marked hyperbolic orbits should result in comets picked up *en route* by a swiftly-advancing sun. The fact that their native movement is practically parabolic shows it to have been wholly imparted from without. They passively obeyed the pull exerted upon them. In other words, their condition previous to being attracted by the sun was one of relative repose. They shared, accordingly, the movement of translation through space of the solar system.

"This significant conclusion had been indicated, on other grounds, as the upshot of researches undertaken independently by Carrington and Mohn in 1860, with a view to ascertaining the anticipated existence of a relationship between the general *lie* of the paths of comets and the direction of the sun's journey. It is tolerably obvious that, if they wander at haphazard through interstellar regions, a preponderance of their apparitions should seem to arrive from the vicinity of the constellation Hercules; that is to say, we should meet considerably more comets than would overtake us, for the very same reason that falling stars are more numerous after than before midnight. Moreover, the comets met by us should be apparently swifter-moving objects than those coming up with us from behind; because, in the one case, our own real movement would be added to, in the other subtracted from theirs. But nothing of all this can be detected. Comets approach the sun indifferently from all quarters, and with velocities quite independent of direction." *

Thus the hypothesis of the translation of the solar system through space, at a velocity of from ten to twenty miles a second, is unavoidably burdened with the supposition that even the great comets, some of which recede from the sun more than fourteen times the distance of Neptune, are regular members of the solar system, and in addition to an orbital movement which some of them are thought to require thousands of years to complete, are carried with the sun through space as if parts with him of one rigid system! As we shall presently see that there is a powerful objection to the hypothesis that comets participate in a motion of solar translation, the fact that they are undoubtedly members of our system casts doubt upon the entire postulate of solar translation.

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* Clerke's "History of Astronomy." Third edition, 1893, pp. 448–9.

18. In the cases of the great comet of 1668, the great comet of 1843, the great southern comet of 1880, the great comet of September, 1882, and the comet of January, 1887, the apparent identity of orbits and likeness of physical constitution was such as to create a most perplexing problem. The comet of 1668 we may leave out of the question, the information respecting it being somewhat vague. The great comet of 1843 has been referred to elsewhere in this pamphlet. At perihelion the centre of its nucleus was but 78,000 miles from the sun's surface, the distance between the surface of the comet's head and the sun being 32,000 miles or less. The crimson prominences, or solar flames which rise from the chromosphere, often extend farther from the sun than this, while the coronal matter is always in evidence more than ten times this distance from the sun. Hence, in sweeping around the sun for 180 degrees at this distance from his surface—a feat which was performed in two hours and eleven minutes, the velocity at perihelion being 366 miles a second—the head of this comet was plunging through the sun's atmosphere. Since the extremity of the tail apparently swept through the semi-circumference of a vast circle in the same time, we must either suppose that the comet switched its tail through this immense space as if it were a rigid appendage, or else (more rationally) conclude that material particles constantly shot from the nucleus to the extremity of the tail with nearly the velocity of light, so that a new tail was formed at every stage in this swift sweep. Different computations of the period of this comet ranged from 533 to 6 years, but by most astronomers a period of 175 years was accepted, based upon a supposed identification with the great comet of 1668, which apparently described a very similar orbit.

On January 31, 1880, the great southern comet was discovered, remaining visible in the southern hemisphere for about twenty days. Its appearance at once suggested the great comet of 1843 to some observers. But although it developed a tail of astonishing length, both nucleus and tail were much less brilliant than those of its great predecessor, while it faded from view much sooner. Nevertheless it almost touched the sun at perihelion, like the comet of 1843, swept through the solar atmosphere with a like velocity, passing through 180 degrees in a little more than two hours; and described a section of an orbit which could not be distinguished from that calculated for the comet of 1843, according to the independent computations of Dr. Gould, Dr. Copeland and Mr. Hind. This would be explained by identifying the comets of 1843 and 1880 and assigning to them a period of thirty-seven years. But it seems most improbable that a comet so conspicuous, with a period comparatively so short, should have been observed only on these two occasions. Oppolzer proposed the hypothesis that in the apparition of 1843 we witnessed the first visit to our system of a comet pursuing a parabolic orbit, but that a resisting medium, very dense near the sun, changed its path to an ellipse, bringing it back in 1880. But the postulate of such a resisting medium appears absolutely untenable, as we shall see presently. Klinkerfues thought that such a medium had progressively reduced the periods of the comet of 371 B. C., so that it returned in 1668 A. D., 1843 and 1880. But besides the objection as to a resisting medium, the attempted identification with the comet of 371 B. C. is forced; while according to this hypothesis the comet should have returned in 1897, an appointment which it failed to keep, unless in an invisible form. But there is the alternative view that these are distinct comets pursuing practically the same orbit—perhaps fragments of an enormous comet which at some time suffered a process of division like that observed in the case of Biela's comet. For while the identity of the orbits of the comets of 1843 and 1880 was ascertained, they were observed through sections of their orbits so small that their periods could not be accurately determined.

On September 3, 1882, a great comet was discovered at Auckland, New Zealand, while at the Cape of Good Hope it was observed from September 8 through its perihelion passage, which occurred on September 17. The comet performed a transit across the sun, at a distance of less than 300,000 miles from his surface. It was visible in daylight for three days, and remained visible to telescopic inspection until June, 1883. The most careful computations of its elements showed that its orbit was almost, but not exactly, coincident with that of the comets of 1843 and 1880. But the hypothesis of identity with them, with periods remarkably shortened by a resisting medium which rapidly increases in density toward the sun, was refuted by the observations of this comet; for it was carefully watched both before and after perihelion, and when it emerged from the sun's atmosphere not the slightest retardation was perceptible. Moreover, its observation through a greater distance than had been possible in the case of any other comet enabled its period to be determined within certain limits, indicating that it must be between 772 and 1000 years. It cannot, therefore, be identified with the comets of 1668, 1843 or 1880.

On January 18, 1887, another great comet was observed from the southern hemisphere, passing out of range about ten days later. In its appearance, in its passage around the sun for 180 degrees in almost two hours, nearly grazing his surface, and in the elements of its orbit, it revealed the most remarkable similarity to the great southern comet of 1880. The likeness between these two comets and that of 1843 is much greater than between them and the comets of 1668 and of September, 1882, and it is not impossible that the three first mentioned are one, with a period of seven years. Indeed, it is well known that Clausen considered the period of the great comet of 1843 to be six or seven years, although not many have followed him in this conjecture. The fact that the comets of 1880 and 1887 were less brilliant than that of 1843 could be explained either as a reduction in volume on account of frequent returns to perihelion, or as a periodic reduction in brilliancy due to changing electrical conditions, periodic variations of this kind being manifest in some other cases. The most serious objection to the hypothesis of a seven-year period for such a comet is the failure to perceive it on so many occasions. We could scarcely account for this except on some electrical theory of illumination permitting the conjecture that in some cases comets may pass perihelion without attaining a luminosity which renders them visible. But we have no experimental data justifying such a view. By most astronomers, therefore, it is now supposed that the comets of 1843, 1880 and 1882, whose orbits are indistinguishable, are sections of a larger comet which originally described the same orbit until the process of disintegration set in, while very slight retarding or accelerating influences have altered the periods of the fragments without altering materially their orbits. Under this hypothesis the comets of 1668 and of September, 1882, might also be considered fragments of the same original comet.

19. The great comet of 1807 and Tebbutt's comet of May, 1881, present another example of identity of orbits. An identity of the comets themselves, however, seems out of the question in this case. For Bessel's calculation of the period of the comet of 1807, making it more than fifteen hundred years, is considered approximately correct; and since the hypothesis of a resisting medium is apparently no longer tenable, its reappearance in 1881 would be quite inexplicable. The unusual length of time during which Tebbutt's comet remained in view, on the other hand, afforded an excellent opportunity for computing its period, which is thought to be about three thousand years—a determination utterly irreconcilable with its identification with a comet which appeared but seventy-four years before. Hence the undoubted identity of orbits in this case is by most considered a confirmation of the view that the comets of 1807 and of May, 1881, are components of a disintegrated comet which once described the same orbit, while retarding or accelerating influences have altered the periods of the two components without materially altering their orbits.

The hypothesis of groups of related comets was advanced by Clausen in 1831, and developed by Hoek in 1865, the evidence in its favor being then confined to the knowledge that in many cases several comets could be grouped together in virtue of the fact that their orbits intersected at a common point remote from the sun. From this it was argued that the disintegration of a large original comet at the point of intersection had probably produced the different members of the group.

20. The view just mentioned may be said to derive an air of probability from the history of the Lexell-Brooks comet. After its appearance in 1770 its orbit was calculated by Lexell, who assigned to it a period of five and one-half years. Burckhardt also computed its elements, arriving at the same conclusion. Nevertheless it had not been observed before 1770, and was not seen after that date until 1889. Lexell, Laplace and Leverrier calculated

that it had closely approached Jupiter in 1767, when its orbit received the modification which brought it within the range of terrestrial observation in 1770. Failure to observe it five and one-half years later could be accounted for by its unfavorable position with respect to the earth. In 1779 Jupiter again approached the part of his orbit described in 1767, and it is supposed that his influence on this occasion modified the comet's orbit so as to withdraw it from terrestrial observation.

When the orbit of a comet discovered by W. R. Brooks, July 7, 1889, was calculated, it was found to have a period of seven years and to belong to the family of Jupiter. At one time it appeared as three distinct comets, parallel to one another, although by some observers a very faint nebulous atmosphere was seen to embrace them all. Through the investigations of Dr. Chandler and Mr. C. L. Poor the identity of this comet with that of Lexell was apparently established. It was calculated that Brooks' comet must have passed very close to Jupiter at the time (1779) and place when and where Lexell's comet was supposed to have met that planet; that between 1779 and 1886 Brooks' comet probably made three revolutions in an orbit extending from that of Jupiter towards the limits of the solar system, in the course of which it was much influenced by Saturn—approximately the programme which Leverrier had predicted for Lexell's comet as a consequence of its supposed encounter with Jupiter in 1779, and that in 1886 Brooks' comet had almost grazed the surface of Jupiter, becoming entangled with one of his moons, which had resulted in breaking up the comet into the three components observed in 1889, while at the same time sending them off in new orbits toward the sun. Bredichin further calculated that the orbits of the three components would intersect about where the supposed encounter with Jupiter occurred in 1886.

21. But if Lexell's comet serves to illustrate the hypothesis that comets describing approximately identical orbits are probably fragments of a disrupted comet, it also emphasizes the general rule that comets describe elliptical orbits about *two* centres of attraction—the sun and some other body. The cometary systems connected with Jupiter, Saturn, Uranus and Neptune bear witness to this fact. And since, upon the disruptive theory, the great comets of 1843, of January, 1880, and of January, 1887, if not also those of 1668 and of September, 1882, must have maintained their present orbits for some time, it is a question whether we ought not to assume that the outer extremities of these orbits are described about some unknown body just as the inner extremities are described about the sun. If we assume this, we could only explain it, on the Copernican basis, by the further assumption that there are unknown planets revolving about the sun in orbits much more distant than that of Neptune. It is calculated that Donati's comet has a period of 2,000 years, its orbit carrying it five and one-half times the distance of Neptune from the sun. To the great comet of 1811 was assigned a period of more than three thousand years, and an orbit extending fourteen times

the distance of Neptune from the sun; while to the Wells comet of 1882 J. J. Parsons assigned a period of 400,000 years! Thraen, however, reduced this to about 3,600 years. If these computations are not entirely out of the question, and the comets be thought of as annexed by unknown planets, it is plain that some of these planets must be exceedingly remote from the sun.

22. If we accept the Tychonic theory, we can even conceive of the orbits of some of the great comets as extending to different stars, since the scale of distances and sizes applied to the stars, under our present conceptions of the physical universe, is not required by Tychonic theory. The fact that the stars do not present measurable disks, as do the planets, is not necessarily an indication of such immense distances as have been assigned to them, but may rather indicate more moderate sizes and a gaseous constitution. Halley's comet, on the 23d of January, 1836, appeared as a star of the sixth magnitude, *without measurable disk*, when much nearer the earth than are the larger planets.

23. Proceeding on the basis of Copernican conceptions, and rejecting the hypothesis that the greater comets describe orbits which extend outward to the vicinity of unknown planets, it follows that since, according to current theory, comets partake in a motion of translation of the solar system through space, we must suppose either (1) that existing comets or their ancestors have existed from the origin of the solar system, when they were made partakers of the initial velocity of translation imparted to the solar system by the Creator, or (2) that interplanetary or extraplanetary space contains nebulous matter (which originally received the velocity of translation imparted to the solar system), fragments of which are drawn into cometary orbits by gravitation or electrical attraction. The first of these conjectures is subject to grave objections. It is very doubtful whether we can attribute to individual comets the long life which evolutionary astronomers attribute to the solar system. Again, we can scarcely conceive of cometary matter as having been a part of the immense nebulous cloud from which, according to evolutionary astronomers, the solar system was evolved, for in that case this matter should rather have gravitated and condensed as portions of planets or planetary satellites. Astronomers seem to be shut up, therefore, to the second conclusion, which Miss Clerke thus expresses:

"We conclude that the 'cosmical current' which bears the solar system towards its unknown goal, carries also with it nebulous masses of undefined extent, and at an undefined remoteness, fragments detached from which, continually entering the sphere of the sun's attraction, flit across our skies under the form of comets. These are, however, almost certainly so far strangers to our system that they had no part in the long processes of development by which its present condition was attained." *

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* "History of Astronomy." Third edition, p. 449.

24. To incorporate with the solar system nebulous masses of "undefined extent" is to suggest a form of resisting medium in space. But the existence of such a medium appears now to be pretty well discredited. It is clear that the planets are not perceptibly retarded by such a medium. To account for this, it was once supposed that the medium consists of tenuous matter which accompanies the planets in their revolutions. But such a medium should retard comets which have a retrograde motion,—*i. e.*, move in a direction opposite to the movement of the planets—so that when it was found that Halley's comet was not so retarded, this hypothesis was discountenanced. The retardation observed in the case of Encke's comet, inexplicable as an effect of planetary influences, was long thought to indicate the existence of a resisting medium; but when the retardation of this body was found to be a variable quantity, it could no longer be rationally attributed to such a cause. Encke conceived of a resisting medium which rapidly increases in density toward the sun, and this is what we should naturally expect as the result of the sun's gravitation, provided that interplanetary space is filled with attenuated matter. But this theory is utterly irreconcilable with the undoubted fact that the great comet of September, 1882, must have plunged through any medium which surrounds the sun, yet experienced no perceptible retardation, notwithstanding that the nucleus of the comet was so small, and its surrounding matter so attenuated, that it was invisible while performing a transit of the sun.

The moment we accept the Tychonic theory of the universe all difficulties vanish which arise out of the current conception of a translation of the solar system through space. Moreover, on the Tychonic basis, we can conceive of comets which are permanent members of the solar system and yet describe orbits extending to some of the stars.

25. Encke was led to the postulate of a resisting medium in interplanetary space by the observations of the planet bearing his name, which showed that its orbit was gradually contracting and its period diminishing from the operation of some cause other than the influences of the members of the solar system, for which full allowance was made. This phenomenon could not be attributed to the attraction of some unknown body, for the other effects which such a body should produce were not apparent. But the subsequent investigations of Von Asten and Backlund, while confirming Encke's conclusions for the period covered by his researches, demonstrated that in 1868 the contraction of orbit and shortening of period noted by Encke had suddenly diminished one-half—a change which certainly remained stable down to 1885. Nor was there any evidence which observation could detect of a change in the mass of the comet. The whole matter remains a mystery to the present time. It is quite possible, however, that we have a periodical phenomenon to deal with; and by assuming that the attractions involved in the case are of an electrical rather than a gravitational nature, such changes, whether periodical or permanent, could be

easily accounted for on the basis of slight alterations of electrical states of comet or sun, or both. In estimating the mass of Mercury, on the basis of its influence upon this comet, when the latter was in its vicinity, it is a notable fact that careful investigators like Von Asten and Backlund obtained wholly unreconcilable results. Dealing with the period of 1818–48, Von Asten calculated the mass of Mercury at only one-half the mass deduced by Backlund on the basis of the influence exerted by the planet on the comet in 1878. Provided that the attraction is electrical, an actual difference in the attractive force at the two periods may have resulted from a change in the electrical condition of the comet. Another phenomenon having bearing in the same direction is the fact that Encke's comet varies greatly in brightness at different times, sometimes appearing with a tail and sometimes without one, sometimes developing a nucleus and sometimes appearing without one, while yet there is no evidence of disintegration nor of a progressive decrease in brilliancy. These fluctuations are, in fact, scarcely explicable by any other than an electrical theory of illumination.

26. An energy more powerful than gravitation, acting between the two bodies of matter into which Biela's comet split in January, 1846, is referred to by Miss Clerke, as follows: "At a distance from each other of about two-thirds the distance of the moon from the earth, the twin comets meantime moved on tranquilly, so far, at least, as their course through the heavens was concerned. Their extreme *lightness*, or the small amount of matter contained in each, could not have received a more signal illustration than by the fact that their revolutions around the sun were performed independently; that is to say, they traveled side by side without experiencing any appreciable mutual disturbance, thus plainly showing that at an interval of only 157,250 miles their attractive power was virtually inoperative. Signs of internal agitation, however, were not wanting. Each fragment threw out a short tail in a direction perpendicular to the line joining their centres, and each developed a bright nucleus, although the original comet had exhibited neither of these signs of cometary vitality. A singular interchange of brilliancy was, besides, observed to take place between these small objects, each of which alternately outshone and was outshone by the other, while an arc of light, apparently proceeding from the more lustrous, at times bridged the intervening space. Obviously, the gravitational tie, rendered powerless by exiguity of matter, was here replaced by some other form of mutual action, the nature of which can as yet be dealt with only by conjecture."*

Whether we proceed on a Copernican or a Tychonic basis, it must be apparent to a reflecting mind that many of the facts which we have thus brieflly reviewed are only explicable when we assume that electrical forces play an important part in the economy of comets. This view of the matter in fact now generally prevails among astronomers, although the hypotheses thus far advanced proceed on a Newtonian-Copernican basis. Olbers was the first astronomer of note to account for the formation of comets' tails as a phenomenon of electrical repulsion, this theory suggesting itself to him as the result of his observations of the great comet of 1811. The essentials of his hypothesis we present in the words of Miss Clerke, from whose excellent and accurate work we have drawn so freely:

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* *Ibid.*, p. 120.

"The paraboloidal shape of the bright envelope separated by a dark interval from the head of the great comet of 1811, and constituting, as it were, the *root* of its tail, seemed to the astronomer of Bremen to reveal the presence of a double repulsion ; the expelled vapors accumulating where the two forces, solar and cometary, balanced each other, and being then swept backward in a huge train. He accordingly distinguished three classes of these bodies: First, comets which develop *no* matter subject to solar repulsion. These have no tails, and are probably mere nebulosities, without solid nuclei. Secondly, comets which are acted upon by solar repulsion *only*, and consequently throw out no emanations *towards* the sun. Of this kind was a bright comet visible in 1807. Thirdly, comets like that of 1811, giving evidence of action of both kinds. These are distinguished by a dark *hoop* encompassing the head and dividing it from the luminous envelope, as well as by an obscure caudal axis, resulting from the hollow, cone-like structure of the tail.

"Again, the ingenious view recently put forward by M. Bredichin as to the connection between the *form* of these appendages and the *kind* of matter composing them, was very clearly anticipated by Olbers. The amount of tail-curvature, he pointed out, depends in each case upon the proportion borne by the velocity of the ascending particles to that of the comet in its orbit; the swifter the outrush, the straighter the resulting tail. But the velocity of the ascending particles varies with the energy of their repulsion by the sun, and this again, it may be presumed, with their quality. Thus multiple tails are developed when the same comet throws off, as it approaches perihelion, specifically distinct substances. The long, straight ray which proceeded from the comet of 1807, for example, was doubtless made up of particles subject to a much more vigorous solar repulsion than those formed into the shorter curved emanation issuing from it nearly in the same direction. In the comet of 1811, he calculated that the particles expelled from the head traveled to the remote extremity of the tail in eleven minutes, indicating by this enormous rapidity of movement (comparable to that of the transmission of light) the action of a force greatly more powerful than the opposing one of gravity. The not uncommon phenomena of multiple envelopes, on the other hand, he explained as due to the varying amounts of repulsion exercised by the nucleus itself on the different kinds of matter developed from it." *

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* *Ibid.*, pp. 123-5.

Bessel arrived at similar conclusions from his study of the formation of the tail developed by Halley's comet in 1835. The peculiarity of this formation, and Bessel's inference from it, is thus given by Miss Clerke:

"Some curious phenomena accompanied the process of tail formation. An outrush of luminous matter, resembling in shape a partially opened fan, issued from the nucleus *towards* the sun, and at a certain point, like smoke driven before a high wind, was vehemently swept backward in a prolonged train. The appearance of the comet at this time was compared by Bessel, who watched it with minute attention, to that of a blazing rocket. He made the singular observation that this fan of light, which seemed the source of supply for the tail, oscillated like a pendulum to and fro across a line joining the sun and nucleus, in a period of four and three-fifth days; and he was unable to escape from the conclusion that a repulsive force, about twice as powerful as the attractive force of gravity, was concerned in the production of these remarkable effects. Nor did he hesitate to recur to the analogy of magnetic polarity, or to declare, still more emphatically than Olbers, 'the emission of the tail to be a purely electrical phenomenon.'" *

Professor W. A. Norton, as we have seen, in 1844 applied the theory of solar electrical repulsion to the explanation of sun-spots and the expulsion of coronal matter. He also applied it to comets. The appearance, in 1858, of the great comet known as Donati's led to a revival of the electrical theory of Olbers and Bessel, while the changing phases of this brilliant object were described and illustrated in a work published in 1862 by Professor Bond, of Harvard College, whose record of his careful telescopic observations won for him the gold medal of the Royal Astronomical Society of London.

Professor Pierce advanced the hypothesis that comets are simply very large meteorites, having a solid, metallic nucleus at least as dense as iron, which in the cases of large comets may be hundreds of miles in diameter. Or, instead of being solid, the nucleus may consist of a closely-packed conglomeration of solid meteorites. This mass is surrounded by gases generated from the solid matter, which shine partly with reflected sunlight and partly in virtue of being rendered luminous by electric discharges of slight intensity. As the comet approaches the sun, the solid nucleus is slightly vaporized, forming the coma and tail, while the latter streams away under the stress of an energy of electrical repulsion. In the words of Professor Pierce, "In its approach to the sun, the surface of the nucleus is rapidly heated: it is melted and vaporized, and subjected to frequent explosions. The vapor rises in its atmosphere with a well-defined upper surface, which is known to observers as an *envelope*. . . . The electrification of the cometary mist is analogous to that of our own thunder-clouds. Any portion of the coma which has received the opposite kind of electricity to the sun and to the repelled tail will be attracted. This gives a simple explanation of the negative tails which have been sometimes seen directed towards the sun. In cases of violent explosion the whole nucleus might be broken to pieces, and the coma dashed around so as to give varieties of tail, and even multiple tails. There seems, indeed, to be no observed phenomenon of the tail or the coma which is not consistent with a reasonable modification of the theory."

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* *Ibid.*, pp. 126-7.

His study of Donati's comet led Professor Norton to present a fuller development of the theory of electrical repulsion, his conclusions being published in the "American Journal of Science," and summarized in his "Treatise on Astronomy." He recognized, as Olbers had done, "*an inequality in the force of repulsion* exerted by the sun upon different portions of nebulous matter expelled from the nucleus;" and concluded that in the case of Donati's comet "nearly one-half of the tail, on the concave side, was made up of matter that was not actually repelled by the sun, but became widely separated from the head of the comet, after being expelled by a projectile force beyond the sphere of attraction of the nucleus, simply because it was subject to a diminished intensity of solar attraction." He opposed the then prevalent view that the source of the tails of comets was the envelope or envelopes of the head, declaring the preponderating weight of evidence to be "in favor of the theory that the envelope and tail are but different portions of one continuous stream of cometic matter emanating from the nucleus, or from the bright nebulosity contiguous to the nucleus proper;" while he declared it "possible to deduce the actual form and dimensions of both the envelope and tail on the hypothesis of a single continuous stream proceeding from a certain portion of the nucleus exposed to the action of the sun." His conclusions respecting the constitution and mode of formation of the tails of comets he summarized in the following postulates:

"1. The general situation of the tail of a comet with respect to the sun shows that the sun is concerned, either directly or indirectly, in its formation. The changes which take place in the dimensions of a comet, both in approaching the sun and receding from it, conduct to the same inference. 2. Since the tail lies in the direction of the radius-vector [the straight line from the sun] prolonged beyond the head, the particles of matter of which it is made up must have been driven off by some force exerted in a direction from the sun. 3. This force cannot emanate from the nucleus, for such a force would expel the nebulous matter surrounding the nucleus in all directions, instead of one direction only. It is, however, conceivable that, as Olbers supposes, the nebulous matter is, in the first instance, expelled from the nucleus by its repulsive action, taking effect chiefly on the side towards the sun, and afterwards driven past the nucleus into the tail by a repulsion from the sun. 4. There seems, then, to be little room to doubt that the matter of the tail is driven from the head by some force foreign to the comet, and taking effect from the sun outwards. 5. This force, whatever may be its nature, extends far beyond the earth's orbit; for comets have been seen provided with tails of great length, though their perihelion distance exceeded the radius of the earth's orbit (*e. g.*, the great comet of 1811). 6. It is natural to suppose that, like all central forces, *the repulsive force exerted by the sun upon cometic matter varies inversely as the square of the distance.* This law of variation has in fact been established by the investigations of Bessel and Professor Pierce, and confirmed by the author's determination of the form and dimensions of the tail of Donati's comet, upon the theory that it was made up of particles individually repelled by the sun with an intensity of force varying according to this law. (See 'American Journal of Science,' Vol. xxix., pp. 79 and 383, and Vol. xxxii., p. 54, &c.)"

As a matter of fact, the train of Donati's comet, as determined by actual observations, revealed a remarkable agreement with that deduced by Prof. Norton on the basis of his theory. We cannot take space to give in full Norton's demonstration that his theory of an electrical force offered a rational explanation of the various minutiæ observed in the case of Donati's comet, but his fundamental conception of the expelling forces in operation is summarized in the following paragraphs:

"Since the cometic particles which were distributed along the concave side of the tail of Donati's comet were not repelled by the sun, we must infer that they were not expelled from the nucleus by a force of repulsion, but were in all probability detached by some projectile force in operation at or near its surface. On the other hand, the cometic particles that were in a condition to be repelled by the sun, may have become detached from the nucleus under the operation of a force of repulsion exerted by its mass, or from its surface. We may conceive a repulsive force, exerted by both the nucleus and the sun, to be a consequence of the particles being more nearly in the condition of the ultimate molecules, in which there is reason to believe that they become subject to both a molecular and a heat repulsion, operating at indefinitely great distances. (See 'American Journal of Science,' Vol. xxxviii., p. 70.)

"If we conceive the bright nebulous mass adjacent to the nucleus, which appears to be the fountain head of the nebulous stream that constitutes both the envelope and train of a comet, to be in a magnetic condition similar to that which has been attributed to the photosphere of the sun, it is to be observed that particles may become detached from the tops of magnetic columns simply in consequence of a diminution in the magnetic intensity of the nucleus and its photosphere; and such diminution of magnetic intensity should continually occur, from day to day, as the comet recedes from the sun, and consequently has a decreasing velocity in its orbit. For, according to the *theory of cosmical magnetization*, the intensity of the magnetic currents developed should be directly proportional both to the orbital velocity and the velocity of rotation. (See 'American Journal of Science,' Vol. xli., p. 62.) A statical force of electric repulsion might also operate to detach particles, whether magnetic or not, in directions normal to the surface of the nucleus.

"The projectile force, whose existence we have here recognized, may have its origin in electric discharges along magnetic vaporous columns, like the similar force supposed to be in action upon the surface of the sun's photosphere. In support of this view it may be urged that, if we assume the hypothesis that the nebulous matter at the nucleus of a comet is made up of particles susceptible of magnetization, and capable of being expelled by discharges along lines of magnetic polarization, we are enabled to give an adequate explanation of diverse luminous phenomena presented by comets, that are wholly inexplicable upon all previous hypotheses." *

Observations of Donati's comet also led Dr. C. F. Pape, of Altona, to give his adherence to the theory of solar electrical repulsion; and recognizing that the straight and scimitar-shaped tails developed by this comet must be effects of different energies of repulsion, he calculated numerical values for each.

Zöllner, in 1871, attempted to reconcile the force of solar electrical repulsion with that of solar gravitational attraction. He remarked that gravity depends upon the mass of matter, and electricity upon the surface of the body acted upon, so that as the particles of matter diminish, the effect of gravity becomes less and the effect of electrical repulsion increases. Therefore the more solid nucleus of comets may continue to gravitate toward the sun, while the finely-divided particles are driven off by solar electrical repulsion, it being assumed, of course, that the sun and comets are similarly electrified. He justly remarked that an electrical charge of moderate intensity would probably produce the various phenomena of illumination and repulsion exhibited by comets. In 1872 he maintained that, far from being at a loss to account for the existence of electrical disturbances in connection with comets, it would rather be difficult to explain their absence, since the approach of such bodies to the sun must inevitably induce evaporation and other processes which would in turn produce an electrical stress of considerable intensity.

We would remark that the first part of Zöllner's theory is one which should be demonstrated experimentally and not assumed. It would be absurd to suppose that the gravitation of a given mass of matter, or the attraction exerted upon it by another mass, diminishes in the least degree when the matter is finely-divided; nor do we suppose that Zöllner intended to suggest such an idea. †

For Newton's theorem presents gravitation as an unvarying energy, proportional to the mass of matter investigated, so that the attraction of the sun's mass for a comet is but the sum of its attractions for each particle of the comet's mass, and does not vary, so long as the number of cometary

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* The above quotations are from Norton's "Treatise on Astronomy," fourth edition, 1878, pp. 239, 241, 237-8 and 242.

† We have access to his views only through Miss Clerke's representation of them.

particles is intact, whether they are closely-packed or finely-divided. But recognizing that the gravitation in question (if such a force exists) is an invariable quantity, much may be said for the hypothesis that electrical repulsion of a given intensity can produce much greater effects upon a given mass of matter in a finely-divided than in a dense condition. Yet this question should be determined experimentally.

For ourselves, we would dismiss the postulate of gravitation, and account for the greater effect of a given amount of electrical energy upon a given mass of matter in a gaseous than in a solid form upon an entirely different principle. The preliminary process whereby the solid matter has been changed to a gaseous condition must have largely overcome the molecular attraction, not the gravitation of the mass, which would involve the absorption by the gaseous molecules of a certain amount of heat-energy. Hence they would already be in a state of rapid vibration, and being already brought to this state, the electrical energy applied to them could be more completely utilized in imparting impulsive and repulsive phenomena than it could be if it must be largely expended in overcoming molecular attraction before it could gain access to the interior molecules, or than it could if utterly unable to overcome the molecular attraction of the mass, in which case it would accumulate as statical charges upon the surface of the solid body.

Dismissing gravitation as a *non-est*, we would explain as electrical phenomena both the attraction of the sun for the nucleus of comets and its repulsion for the matter constituting their tails. As we have shown in the preceding chapter, this is precisely what we should expect, provided that electrostatic induction takes place as the comet approaches the sun. The reader is referred to the paragraph marked "F" at the close of Part VI.

Professor Bredichin was led by his study of the development of comets' tails, 1874-82, to divide comets into three classes, characterized by the intensity of the repulsive forces to which they are subject. In his first class are Halley's comet and such great comets as those of 1744, 1811, 1843 and 1861, which develop exceedingly long tails formed of particles projected in straight rays. The repulsive energy which produces such effects he calculates is about fourteen times as powerful as gravitation—in the case of the great comet of 1811, it was more than seventeen times as powerful as the gravitational pull. In his second class are the comets which develop curved tails, Donati's being an example. Here he calculates that repellant energies of varying intensities are at work, ranging from twice to but one-half the force of gravity. In his third class the repulsive energy at work is supposed to be considerably less than one-half that of gravity, so that the development of a tail is simply due to the fact that the comet's head leaves the matter in the tail behind, although the latter is also actually traveling toward the sun. Prof. Bredichin proposes to explain these different varieties of tails on the hypothesis that they are formed of different kinds of matter, hydrogen being characteristic of his first class, hydro-carbons of his second, and iron of his third. The relative molecular weights of these substances are about inversely proportional to the repellant energy predicated by Prof. Bredichin for his three classes of comets' tails, and it is assumed in the theory that the atomic weights of the elements represent the comparative pulls of gravity to which the respective atoms are subject. But while spectroscopic analysis has demonstrated that hydro-carbons are characteristic of comets, and that iron is sometimes a constituent, it has never revealed the presence of hydrogen in these bodies.

It seems plausible, however, to suppose that the molecules of the different substances which constitute the matter of comets will be repelled by a given electrical repulsive force with velocities inversely proportional to the respective molecular weights (the molecular weight being, of course, the sum of the weights of all the atoms in each molecule). This would be in perfect accord with the theory we advocate, namely, that the atomic weights of the elements do not represent the relative degrees of their response to the solicitation of gravity at the earth's surface, but represent the relative degrees of response to the solicitation of terrestrial magnetic attraction, arising from their situation in the magnetic field of the earth. According to this view, if the electrical attraction of the sun for hydrogen is about one-twelfth of its electrical attraction for carbon, as indicated by the atomic weights, one and twelve respectively, then a given energy of solar electrical repulsion should be twelve times as effective in expelling hydrogen as in expelling carbon.

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We add a few remarks on periodic meteor-showers. At the time of the famous fall of meteors, November 12, 1833, Professor Olmsted, of Yale, noticed that these bodies appeared to come from one point in the sky, from which fact he reasoned that they must be members of a cloud of particles pursuing about the sun parallel orbits which intersect the earth's orbit. A less brilliant shower having been witnessed in Europe the preceding year, he assigned to this meteoric cloud a period of about 182 days. It was recalled, however, that Humboldt had reported a shower not unlike that of 1833 on the night of November 12, 1799, which led Olbers to suggest a period of thirty-three or thirty-four years. Adolf Erman in 1839 suggested that the meteoric particles probably revolved about the sun in a closed ring, rather than in a cloud. This would account for annual showers, as well as for more brilliant periodic displays, depending upon the period in which an especially dense portion of the ring returned to perihelion. Taking up the investigation in 1864, Prof. H. A. Newton, of Yale, traced back a periodical recurrence of brilliant meteoric showers to 900 A. D., the period between the two successive showers being about thirty-three and one-fourth years. He accordingly predicted a recurrence of the phenomenon of 1833 and 1799 on November 13 or 14, 1866. The prediction was fulfilled. While Prof.

Newton proposed to account for this recurrence by assigning to the meteor ring an orbital period of three hundred and fifty-four and one-half days, Prof. Adams reasoned that the orbital period must in this case agree with the periodic recurrence. Leverrier took the matter in hand, and in 1867 published his calculation of a meteoric orbit extending from the earth beyond the planet Uranus, which agreed, as Dr. Peters pointed out, with that computed for Tempel's comet of 1866 by Oppolzer. The inference was natural that the meteoric ring consisted of the débris of this comet. These "shooting-stars" are known as the November meteors, or Leonids, the point in the sky from which they appear to radiate being situated in the constellation Leo.

On August 10 culminates an anual meteoric shower, that of the August meteors, or Perseids, as they are called, their radiant point being in the constellation Perseus. The orbit computed for them is identical with that computed for the brilliant comet of August, 1862, and extends from the earth far beyond Neptune. It requires about one hundred and twenty-four years for each meteor to make the circuit of this immense orbit, and since all the annual showers are of about equal brilliancy, Copernican theory requires us to believe that the meteoric particles are evenly distributed in a cloud-ring coincident with such an orbit.

A comet which appeared in 1861 is supposed to move in the same orbit as the April meteors, whose annual appearance occurs on the 20th of that month. They are also called Lyraïds, their radiant point being in the constellation Lyra.

The disintegration of Biela's comet in 1845-6, and its failure to appear after 1852, have been referred to. In 1867 three investigators announced that the meteors having their radiant point in the constellation of Andromadæ, showers of which were witnessed in 1798, 1830, 1838 and 1847, probably describe an orbit identical with that of Biela's comet, and it was thought that a meteor-shower might be expected in 1872, when the comet, if still in existence, should have been in a favorable position for observation. The Andromades, as these meteors are called, were seen in large numbers, as expected, together with a comet which may have been a fragment thrown off prior to the first regular observations of Biela's comet. Showers from the radiant point in the Andromadæ were also witnessed in 1885 and 1892, not far from the time when the comet might have been expected to return to perihelion.

Such coincidences go far to justify the hypothesis that comets often suffer disintegration, furnishing the materials for meteoric swarms; and especially so in view of the fact that there are now about eighty supposedly approximate identifications of meteoric orbits with cometary orbits. These facts also go far to justify the hypothesis of Professor Pierce, that a comet is but a huge meteor, or a closely-packed swarm of meteorites, and that if the cometary nucleus is frequently solid, it is no doubt subject to explosions which may reduce it to fragments. And yet some meteoric phenomena are apparently inexplicable on the basis of Copernican theory, as in the case described by Miss Clerke as follows:

"A striking — indeed, an almost startling — peculiarity, on the other hand, divides from their congeners a class of meteors identified by Mr. Denning during ten years' patient watching of such phenomena at Bristol. These are described as 'meteors with stationary radiants,' since for months together they seem to come from the same fixed points in the sky. Now this implies quite a portentous velocity. The direction of meteor radiants is affected by a kind of aberration, analogous to the aberration of light. It results from a composition of terrestrial with meteoric motion. Hence, unless that of the earth in its orbit be by comparison insignificant, the visual line of encounter must shift, if not perceptibly from day to day, at any rate conspicuously from month to month. The fixity, then, of half-a-dozen or more systems observed by Mr. Denning seems to demand the admission that their members travel so fast as to throw the earth's movement completely out of account. The required velocity would be, by Mr. Ranyard's calculation, at least 880 miles a second. But the aspect of the meteors justifies no such extravagant assumption. Their seeming swiftness is very various, and —what is highly significant—it is notably less when they pursue than when they meet the earth. Yet the 'incredible and unaccountable' fact of the existence of these 'long radiants,' although doubted by Tisserand on the ground of its theoretical refractoriness, must apparently be admitted." *

The explanation of the phenomenon of a "fixed radiant" is exceedingly simple on a Tychonic basis, since we have but to imagine a large section of a meteoric ring filing past us in an orbit which has its perihelion near the stationary earth. A difficulty of a different kind is presented to Copernican theory by the Perseids, or August meteors, to which we have already referred:

"Mr. Denning's observations of these yellowish, leisurely meteors extended over nearly six weeks, from July 8 to Angust 16; the point of radiation meantime progressing no less than fifty-seven degrees in right ascension. Doubts as to their common origin were hence freely expressed, especialiy by Mr. Monck of Dublin. But the late Dr. Kleiber proved by strict geometrical reasoning that the forty-nine radiants successively determined for the shower were all in reality comprised within one narrowly limited region of space, In other words, the application of the proper corrections for the terrestrial movement, and for the effects of attraction by which each individual shooting-star is compelled to describe a hyperbola round the earth's centre, reduces the extended line of radiants to a compact group with the cometary radiant for its central point; the cometary radiant being the spot in the sky met by a tangent to the orbit of the Perseid comet of 1862 at its intersection with the orbit of the earth. The reality of the con-

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* "History of Astronomy." Third edition, pp. 412-13.

nection between the comet and the meteors could scarcely be more cogently demonstrated; while the vast dimensions of the stream into which the latter are found to be diffused, cannot but excite astonishment not unmixed with perplexity." *

In this case, again, the perplexity disappears the moment we conceive of the earth as stationary.

We add that every consideration adduced in this chapter to show that the phenomena exhibited by comets are largely inexplicable on any other than an electrical theory of solar repulsion, tends to justify the extension of that theory to solar and planetary phenomena. And since the postulate of universal gravitation apparently cannot be demonstrated by experimental tests, as the existence of molecular attraction, chemical affinity, and electrical and magnetic attraction can be, while all the phenomena attributable to an "occult" energy of gravitation can apparently be rationally accounted for by the operation of forms of energy experimentally known to us, such as electrical and magnetic attraction, we conceive it to be the more rational step to reject the hypothesis of universal gravitation, and to resort to an electrical theory in accounting for the attractions of the solar system as well as for its repulsions. Moreover, if a closer correlation of cosmical forces and effects appears to be practicable on the Tychonic than on the Newtonian-Copernican theory of the universe, we hold that this constitutes a sufficient reason for readjusting our theories in conformity to the cosmical scheme of the great Danish astronomer.

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* *Ibid.*, pp. 413-14.

ERRATA.

Page 31, third line from top.—Change "Sir W. J." to *Sir William G. Johnson, Bart., cousin of General de Peyster.*

Page 34, last line.—Change "or to join" to *and loath to join.*

Page 47, tenth line from top.—Change "later" to *earlier.*

Page 53, fourteenth and fifteenth lines from top.—Should read: *until its original volume was 11,000 times that possessed when nearer the sun.*

Page 63, sixteenth line from bottom.—Change "planet" to *comet.*

ADDENDA.

Imbued with the spirit expressed in the motto of my mother's family, who never hesitated to peril life and substance in the cause they deemed just and right, there is no reluctance in throwing down the gauntlet to the champions of a system which has only gained ground through the very ignorance and blindness of its adversaries, and the latter's real contempt for the authority to which they have professed to cling in other matters—the Bible. Verbal inspiration is the very essence of any authoritativeness which the Scriptures possess, and real faith cannot be the legitimate offspring of anything except belief in such verbal inspiration. Moreover, "*Falsus in uno, falsus in omnibus*," was the just and logical cry of rebellion against this authority among all preceding generations, the Christian element of which was taught to believe in the Bible as Holy Writ. And has this saying now lost its force? Is it logical to utterly refuse the testimony of Scripture on a subject like Astronomy, and yet credit its revelations on other themes? Shall I reject the witness of the Bible in natural things, and at the same time accept its witness in the mysterious domain of supernatural knowledge?

The astronomical issue is not so important as is the question whether the teaching of ages is to be rejected as altogether fallacious. It will not be so rejected unless the bright light which has enlightened the world for thousands of years is to be eclipsed by a "science" which as often errs as it enlightens. But that perennial annunciation, "*Falsus in unum, falsus in omnibus*," will even yet conquer and demonstrate that a fallible "science, falsely so-called," cannot contend victoriously with a Word which was breathed through inspired instruments by the same Creator whose handiwork in nature materialists now madly struggle to disprove.

In this connection I take pleasure in referring the reader to an interesting study in astronomy by Mr. S. H. Parkes, who approaches his theme with a reverence of spirit not often displayed by his compeers, while he deals out some severe blows to the various evolutionary theories of cosmogony. For example, he cites Laplace's famous Nebular Theory of the origin of the universe, only to come to the conclusion that, "Unfortunately for this theory, it has been found wanting in many important particulars, and it is actually contradicted by some well-established facts. The reverse direction of the satellites of Uranus appears to be incompatible with the theory; the exceptional orbits of some of the planetoids and the apparent condensation of Saturn's ring, already referred to, is still more fatal to its correctness."—"Unfinished Worlds: A Study in Astronomy." By S. H. Parkes, F. R. A. S., F. L. D. Second edition, p. 169. London, 1888.

He next refers to the meteoric theory of origins propounded by M. Faye, and since championed by Sir Norman Lockyer and others, which, although conceived with an evolutionary animus that would fain produce a creation without a Creator, finally results in confirming the statement of Genesis i., that *our Earth is older than the Sun.* In the words of Mr. Parkes:

"The latest theory regarding the origin of the solar system is one by M. Faye, in which the solar system is assumed to have been evolved from meteorites, instead of from nebulous matter as suggested by Laplace. This theory has been examined and criticised by competent authorities, and has been found equally at fault as an explanation of existing phenomena. One of the most curious and amusing results of the application of Faye's theory is the necessity it involves of regarding the earth as being older than the sun."—*Ibid.*

Mr. Parkes also discusses the chimerical scheme of Prof. G. H. Darwin, adopted by Sir Robert Ball and others, which accounts for the origin of the Moon by tidal evolution. Sir Robert Ball's presentation of the theory is quoted, and attention is called to the striking fact that, in order to leave the Creator out of the question, he unconsciously endows the MOON *with the intellectual faculties of intelligence and will.* "It may appear somewhat surprising, perhaps," remarks Mr. Parkes by way of comment, "that a learned astronomer should speak of the newly-born moon as having 'adopted' an 'alternative,' and chosen' a course.' This, however, is perhaps in keeping with the novelty of the theory, which reads so much like a story from Laputa that we have thought it well to expound it in the author's own words."—*Ibid.*, pp. 173-4.

But this preposterous conception completely shatters itself upon the rock of chronology, since it absolutely requires vast æons of time which some physicists declare, on physical grounds alone, are out of the question. Thus, in the language of Sir Robert Ball, in order to adopt his scheme, "We are now to look back into the history of the earth and the moon in very remote antiquity. Our ordinary chronologies of thousands of years are here quite inadequate. The unit of time adapted for the earth-moon history is one million of years." In fact, at least 50,000,000 years are required by this hypothesis for the evolution of the moon alone, while, as Mr. Parkes observes, this "fifty millions of years is a trivial matter when compared with the theorist's far-reaching demands upon the future." But what says the competent physicist to speculators who assume that they have unlimited credits with the bank of time? Mr. Parkes answers as follows:

"We should not have referred at so great length to this extraordinary theory had it not been in such direct contradiction to the recent researches of some of our most eminent physicists regarding the probable past and future age of the sun. The settlement of this question is of such paramount importance in the consideration of all questions relating to our solar system, that all theories must of necessity be valueless if framed irrespectively of the data it affords.

"We have already stated, in Chapter IV., the conclusions arrived at by Dr. Young and others on this question [Sir William Thomson, Professor Newcomb, Dr. Young, Professor Langley and others, Prof. Young's conclusion being that our sun cannot have been emitting heat at its present rate for more than eighteen millions of years]. In further reference to the subject we may allude to the lecture given at the commencement of the present year by Sir W. Thomson at the Royal Institution, in which he states most emphatically that 'the past age of the sun, no matter what might have been its origin, whether it came into existence from the clash of worlds pre-existing, or from diffused nebulous matter, could not exceed twenty million years! The physicist, he remarked, treating the subject as a dynamic question, with calculable elements, could come to no other conclusion.

"To a *very considerable extent* within this margin, therefore, the geologist and the biologist must now be content to speculate. If theories of evolution cannot be elaborated without the undefined millions of years which their framers have hitherto demanded, it can only be said, so much the worse for evolution."—*Ibid.*, pp. 175-6.

Thus it is that speculative materialists struggle and flounder in their attempt to escape from the testimony to a Creator in the universe He has framed, until they collide with some impregnable rock of fact which throws them back upon the well-known shore of revealed truth. Among a large number of commendatory letters received since the publication of "The Earth Stands Fast," the following is given as an example of that confidence in Scripture which is far more rational than the credulity which betrays the popular multitude into being swayed, back and forth, like a weather-vane, with every wind of scientific doctrine:

WESTFIELD, INDIANA, Sept. 26, 1900.

GEN. JOHN WATTS DE PEYSTER,
Tivoli, Duchess County, New York.

MY DEAR SIR:—I was agreeably surprised to receive, on the 18th instant, a copy of "The Earth Stands Fast," as insisted in the Lecture of Professor Schoepffer, translated by yourself, with Notes and a Supplement by Frank Allaben. I have read, with intense interest, your translation of the Lecture, the Supplement, and also your Introductory Remarks, your note following the Supplement, and also your Concluding Remarks; and hasten to thank you for having had, by your kindness, the privilege of perusing the work you have thus presented to the public.

Since . . . what I have learned touching the sciences (and of the "oppositions of science, falsely so-called"), has been acquired by personal research, unaided by the personal help of professors and teachers, I cannot claim such attainments as would justify me in expressing a decision in favor of either the Copernican or the Tychonian theory. The whole subject is so awfully sublime and extensive that I am still, in my seventy-third year, an intensely interested searcher for more light) not expecting while I remain in the flesh to attain to a perfect knowledge and understanding of what the learned of past and present generations have failed to understand and conclusively demonstrate. But I am a firm believer in the inspiration and truth of the Bible, and have never found a theory that was set up in opposition to the teaching of that Book that satisfied my mind and judgment so well as the Bible view of the matter.

There is one physical fact that seems to my unscientific mind to support the claim that "the Earth Stands Fast" that is not dwelt upon in the pamphlet you sent me, namely this: The North Star is fixed in the firmament, not far from an angle of forty-five degrees above the horizon, and never rises or sets, nor, perceptibly to the naked eye, changes its position, but to all appearance is absolutely fixed, year in and year out; and then there are vast numbers of other stars that never pass below the horizon, never rise and set, but every twenty-four hours revolve, or to all appearances seem to revolve, around the north star, as a fixed centre of sidereal revolution. I do not understand how this phenomenon can be made to agree with the alleged daily and yearly revolutions of the earth. While I admit that my observations have been superficial, unaided by any instrument, yet anyone with good eyesight can witness what I have imperfectly described any and every clear night in a series of years, as I have done from time to time for more than half a century.

Again, the stability of the north star would seem to me to indicate that the apparent variations of the sun, between the tropics and across the equator, are due to the *actual* movements of the *sun*, and not the result of revolutions of the earth. But enough of these suggestions from one wanting in the advantages of scholastic education.

I notice, in your note appended to Mr. Allaben's Supplement, that, while you endorse his scientific views and deductions, you term part of what he presents "theological abstractions," to which you say you cannot subscribe. May not it be possible that what you term *theological abstractions* are as well founded in truth as are the *scientific views* expressed by Mr. Allaben? What if these *abstractions* helped him "to throw off the shackles of mere superstitious reverence for scientific dogma," and "to soar into the blue depths of the heavens?" It might be well for us to carefully consider those abstractions, even if we cannot subscribe to them, since they seem to minister satisfaction to one so capable of dealing with disputed scientific subjects.

Though I have not the pleasure of your personal acquaintance, I venture the hope that you will regard me as,

Fraternally, your friend,
ROBERT DENNY.

The letters which follow were recently received from Prof. Louis Lange, of Pacific Grove, California, who a few years ago published a pamphlet in German, vigorously attacking the Copernican hypothesis (Chicago, 1895). Rendered in English the title of this paper is "The Untenableness of the Copernican System: An Appeal to the Sound Human Understanding." The letters received from him, which explain themselves, are as follows:

PACIFIC GROVE, CAL., Sept. 22, 1900.

GEN. J. WATTS DE PEYSTER,
New York.

DEAR SIR:—I see your name in connection with a publication upholding the System of Tycho Brahe. I am a firm believer in this system and am deeply interested in your work.

Would you kindly send me your address, and I shall ever consider it a great favor if you would write me some reasons why you undertook this work, and whether there are any prospects of doing away with our present Copernican system. The crushing of this fallacy would be the greatest triumph of our times.

Hoping soon to have the pleasure of hearing from you, I am,

Yours, very truly,
L. LANGE.

PACIFIC GROVE, CAL., Oct. 18, 1900.

GEN. J. WATTS DE PEYSTER,
Tivoli P. O., N. Y.

DEAR GENERAL:—It affords me special pleasure to acknowledge to you the receipt of your two letters, the book, and pamphlets. I was away from home or else you would have heard from me before this. I am now studying with deepest interest what you have sent me.

I have always maintained that the Bible is the only complete and exact text-book on astronomy. It gives, origin, course, purpose, names, end, &c., of the heavenly bodies. If the Bible would err in secular and earthly matters, how could it be our guide in matters eternal and spiritual? How could I trust the Bible when speaking to me concerning the *destiny* of man if it could not tell me the truth concerning his *origin?*

If the Copernican system is correct, then Genesis is a myth. Christ says

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that *the stars shall fall from heaven.* If the Copernican system is correct, this would be an impossibility. Where should the stars fall to, according to the Copernican system? Why, according to it, they are falling continually through space, and we along with them, around some far-off, mysterious centre of gravitation. If the Copernican system is correct, then Christ was only a child of his times.

The Copernican system brought all this trouble into the Christian Church. If it were not for it, there would be no "higher criticism," no theory of evolution." Fell this silly idol of mankind (the Copernican system), and down will come, with a crash, the "theory of evolution" and "higher criticism." The greatest deed of modern times would be the crushing of this hideous fallacy. It would rank with the "*Reformation.*" What changes it would bring about! What strengthening of Christian faith! What activity in publishing new books, as the accumulated scientific trash of our times would then become utterly worthless. To assist in bringing about a revolution of this kind has been the ambition of my life. . . . It is this missionary work we need more than anything else. Then we would send true missionaries among the heathen, not "rationalistic moralists." Then we would have ministers of the gospel in the true sense of the word, and not men who palm off their own wisdom as the gospel.

I hope that you as well as Mr. Allaben will find time to read my pamphlet against the Copernican system. I started from this point of view: As it is extremely easy and simple to prove the rotundity of the earth, so it must be likewise easy and a simple matter to prove that "the earth stands fast." My proofs are those of mathematical geography, and I think are incontrovertible. As soon as the fallacy of the Copernican system shall have been universally acknowledged, then these proofs will be advanced to point out its erroneousness. The trouble now-a-days is that people have no idea of mathematical geography. *Practical* books on geography and astronomy teach that the dome of heaven is a hollow globe, in the centre of which is established the globe of our earth.

The poles of the heavenly globe correspond to those of our globe (earth), and our degrees of latitude and longitude correspond to those of the heavenly globe. Thus, *Capella* is on the 45th degree on the heavenly globe (north). It will therefore stand just overhead on the 45th degree on our earth, when it passes the meridian, or rise on the 45th when seen above the horizon. The celestial equator always corresponds to the equator of our earth. Fixed stars on the celestial equator are always vertically above the earth's equator. All this would be an impossibility if the earth revolved around the sun.

A pamphlet teaching practical geography and astronomy would do an immense lot of good. . . . From a religious standpoint the gain would be incalculable. From a material point of view it might work wonders—the sun, not being so far away, may be taken in hand by the chemist, the physicist, and the electrician. Let us hope and pray that the days of the pernicious Copernican system may be numbered. . . .

Yours very truly,
L. LANGE.

I close these remarks by calling attention again to the fact that the theory of M. Faye, referred to above, leads to the conclusion that "THE EARTH IS OLDER THAN THE SUN." That the earth, in its present condition, is older than the sun in its present condition, is fully borne out by the first chapter of Genesis ; and, if the Bible were read with the same attention that is bestowed upon absolutely worthless books, it would be found to be more scientific than what is so frequently styled "science." According to the first verse of Genesis, "In the beginning God created the heaven and the earth." According to the second verse, the earth then was, or some time subsequently became, "without form and void," while it was from this condition of chaos that God evoked order and the creation as now known to us during the creative "days" described from the third verse onward. On the *first* "day" God said, "Light be, [and] light was," while He "divided the light from the darkness" and "called the light Day and the darkness . . . Night" (vs. 3–5). But it was not until the *fourth* "day" that God said, "Let there be lights in the firmament of the heaven," making a greater light to rule the day and a lesser light to rule the night (Sun and Moon), with the Stars also. This account may be interpreted in either one of two ways :

1. Augustine, styled saint, although not a profound scholar, but yet an acute thinker and complete theologian, and an implicit believer in the truths of the Bible, was of the opinion that what are styled "days" in the account of the Creation were epochs. This would be in perfect agreement with M. Faye's conclusion, for if each "day" is an epoch, three epochs would have intervened between the creation of the earth and the formation of the sun, as we know it.

2. But there is another interpretation which has the merit of allowing all that a rational science can ask, while at the same time conserving the doctrine of verbal inspiration even to the point of recognizing the "days" of Genesis i. as literal days of twenty-four hours each. Verse i., according to this interpretation, speaks of an original creation long prior to the work done in the six days, heaven and earth being called into being. But the next verse speaks of the earth as "without form and void," whereas Isaiah xlv., 18, "according to the original," in speaking of "God Himself who formed the earth," declares that "*not* as waste did He create it." (R.V.) Hence, if the earth was *not* brought into being in a chaotic state, when God originally called it into existence (Gen. i., 1, and Isa. xlv., 18), while it *was* in a chaotic state when he prepared it for man (Gen. i., 2, *et seq.*), then in the two opening verses of Genesis we have a long period predicated, embracing the geological ages : (1) We

have an original creation of heaven and earth, the earth not being "a waste;" (2) The prehistoric geological periods, which may have endured for millions of years; (3) The termination of this long period by a cataclysm which left the earth "without form, and void; and darkness upon the face of the deep," as stated in the second verse of Genesis; and (4) from this chaotic state a remodeling of the earth and solar system *in six literal days*, just prior to the advent of man.

However, whether are intended "literal days," however long, or epochs however protracted, the creation of the earth preceded that of the sun and moon, which were merely called into being in the service of the earth.

N. B.—In "The Earth Stands Fast," I closed the Notes and Supplement with a few lines on page 80 explaining my connection with the labors and opinions of Mr. Frank Allaben, which appear in that Treatise. Such is the extreme modesty and equally remarkable physical working and mental digestive capacity of that gentleman, the reader must be notified that however valuable and original my Suggestions or other assistance may have been, the labor of the preparation must be credited to his efforts, ability and perseverance. Physically I was suffering too much for more than furnishing sources of information, constantly consulting or supervising and finally publishing this treatise styled "Algol."

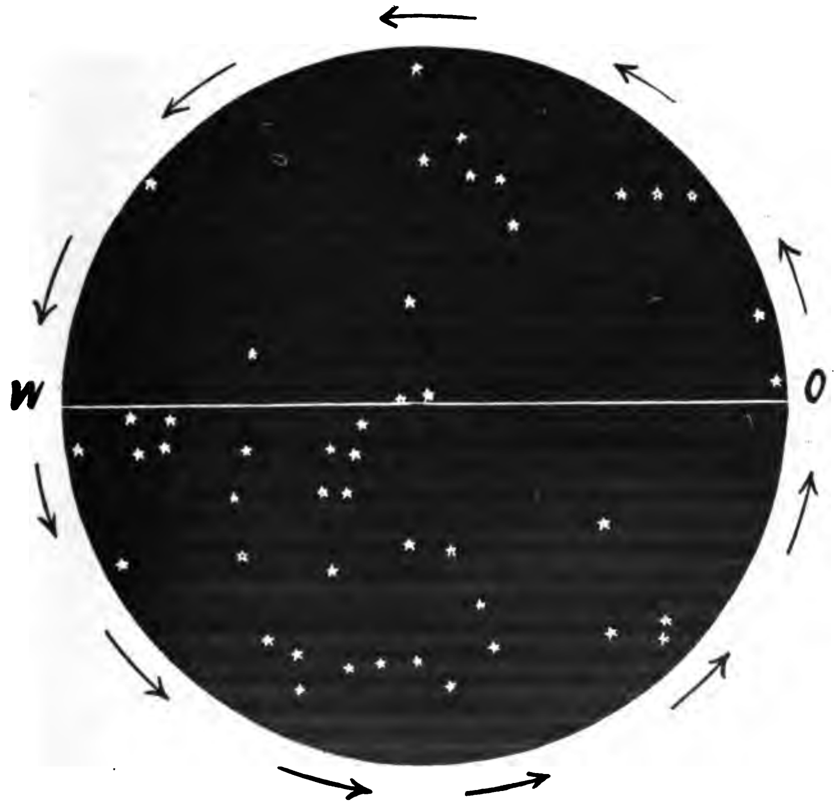
JOHN WATTS DE PEYSTER.

Prof. Louis Lange, in his "Untenableness of the Copernican System," page 5, furnishes a Diagram, which is worthy reproduction, with a translation of the explanatory text, which renders that discussion worthy of a trial on the larger scale as suggested by its author—a trial given it by Professor Lehman, Principal of the Red Hook Normal School. (Moreover, this demonstration in regard to the fixedness of the Polar Star (*Polaris*) is referred to by Professor Lange at pages 4, 5 and 6 of his address, "Die Unhaltbarkeit des Kopernikanschen Systems," is the very idea suggested in the letter of Mr. Robert Denny, pages 77, 78, 79, *supra*.)

Professor Lange does not hesitate to apply very derogatory epithets to Copernicus, which, if his statements and deductions are correct and are not successfully disputed, are fully justified. He says, page 11, "Manifestly Copernicus possessed not one trace [or proof] of a really true investigating mind," and, in another place, "Hence it follows [the development of the system of Copernicus], he annihilates his ridiculous hypothesis with his own explanation."

"Such an investigator, then, is the father of our present speculative astronomical science, which, on top of this, is called the "Queen of the Sciences." To be sure if knowledge and madness stands side by side, then modern, speculative astronomy certainly is "Queen," or the next thing to it.

When we turn our faces toward the North on a starlight night, and look out at the starry heavens, we see that the starry-north-heaven turns itself like a disk around the pole star (*Polaris*), corresponding to the pole-point or pole itself. The stars do not disappear there behind the horizon, but are always visible. The stars between Polaris and the horizon move toward the East, while the stars above Polaris move toward the West.



The star in the centre is Polaris, one and a half degrees from the pole Centre or Pole itself, around which the stars move in the direction indicated by the arrows. This turning of this Star-disk which is visible to the naked eye, is now said to be apparently caused simply by the turning of the earth on its axis. This is what the adherents of the Copernican system maintain. A more ridiculous and more childish assertion cannot be imagined.

If the earth turned on its axis we would observe an entirely different appearance or phenomenon in the northern heavens (also at the south-pole). This can be demonstrated in a practical way. Take a disk [like the one herein presented], only larger, about twelve inches in diameter. Naturally points must be upon it to represent stars. Fasten this disk to the ceiling of the room. Then describe a circle in the room around a table, which stands directly under the disk, with the face turned towards the disk. Then stand still and let another person turn the disk (this is not a very difficult experiment to make). The difference between the actual and seeming or apparent turning of the disk will then be manifest.

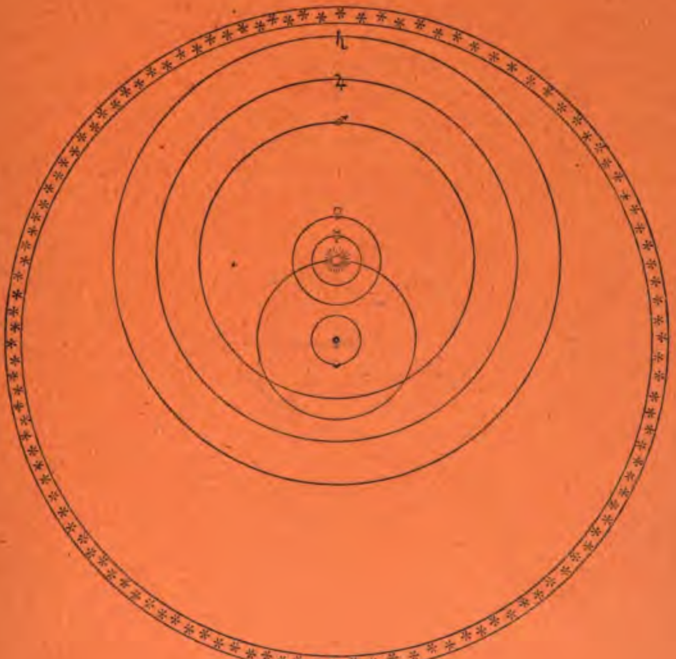
The turning of the star-disk in the polar-circle is not a deception but a reality. It has all the signs of a *real* revolution, while all the signs of a supposititious one are absent or disappear. That this revolution is a real one, is clearly proven by the fact that the part of the disk between the pole star and horizon moves from west to east, and that above the pole star from east to west. Both parts move with the same rapidity. We see also the stars of the lower half of the disk move from west to east.

This would be an impossibility if the stars stood still and we moved ourselves from west to east. Were the latter the case, then all the stars of the polar circle, also those between the pole star and horizon, would evidently have to move toward the west or at times stand still; never could it happen that the one-half of the disk could move from west to east, and the other half at the same time and with the same *rapidity from east to west.*

It must also be borne in mind here, that if the earth really did rotate upon its axis, and we, on the fortieth degree north latitude, do not move towards the stars of the polar circle, but we would pass by them. It is plain, the revolution of the polar disk is real and genuine. That the stars revolve around the north-pole-point every twenty-four hours is based upon facts· But with this the entire Copernican system, which is a miserable fabrication of the [his] brain, is overthrown.

Had Copernicus possessed one vestige of an inquiring mind and a sound human understanding, this distorted unsound misinterpretation of the northern sky could not have escaped his notice. His entire system rests on the observation he made while riding in a wagon, that the houses and trees, &c., seemed to move past him; did he also notice that the objects continue to move with us in the same direction? This observation we make on the starry heaven, founded on fact, that part of the stars move from west to east with the same rapidity of those from east to west. But this is an impossible thing, that a part of the stars could seem to move from west to east, while we ourselves are moving in the same direction, while the stars are standing still. But the observation which we made on the stars within the polar-circle is doubly destructive to the Copernican System, if, in addition, we consider the second movement of the earth, namely, the revolution of the earth around the sun, claimed by Copernicus. It is said that the earth moves with a velocity of twenty miles per second in an orbit of six hundred million miles long around the sun yearly.

Now arises the question: why do we not, in this revolution of the earth around the sun, notice a change in the stars of the polar circle, namely, a passing by of the same? To this the Copernicans answer: the stars are too far away. If this were the case, then should we be absolutely unable to see any, not even one twenty-four hour revolution of the star-disk within the polar circle. The distance which we would travel, for example, on the fortieth degree of north or south latitude in one rotation of the earth of twenty-four hours, would be so very small, compared with the enormous distance of the stars, that a revolution of one of them within the polar circle around the pole could not be perceived." . . . .



TYCHONIAN SYSTEM.